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1. microscope
2. angiosperms
3. food manufacture
4. digestion
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8. irritability
9. heredity
10. plant reproduction
11. animal kingdom
12. plant "
13. ecology

(FW)

A New Manual for the Biology Laboratory

ELEMENTS OF BIOLOGY: A Brief Course for College Students. By *Perry D. Strausbaugh* and *Bernal R. Weimer*. 439 pages, 208 figures, including 11 colored plates. 5½ by 8⅜, cloth.

A NEW MANUAL FOR THE BIOLOGY LABORATORY. By *Bernal R. Weimer* and *Earl L. Core*. 213 pages, 156 figures. 8½ by 11, paper.

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A New Manual for the Biology Laboratory

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FOREWORD TO THE STUDENT *

Louis Agassiz, one of the greatest naturalists, once advised students to "study Nature, not books." The program of the biological laboratory aims to provide an opportunity to obtain at first-hand observation a knowledge of plants and animals which cannot be obtained merely by reading about them and looking at their pictures.

Every true student has an innate curiosity to see and to study plants and animals as they really are, and to observe and investigate for himself. In the laboratory biological problems are proposed which can be solved not so much by trying to recall facts which have been read or heard, but rather by accurate, patient observations of the actual organisms and the study of their fundamental processes. With the help of the microscope acquaintance is made with a most interesting and challenging new world. Moreover, skill is acquired in the use of tools. One learns to "dissect" a frog instead of merely "cutting it up."

The first requisite in the laboratory is keen, meticulous, and patient observation of facts which are accurately and faithfully recorded. A student learns to report only that which he sees, even though it may not agree with written descriptions and pictures. The student should remember that the specimen is always right. Thus, a student becomes imbued with the spirit of the scientific method and has an opportunity for training in its use. Briefly stated, this method involves *observation*, *experimentation*, *analysis*, and *conclusions*. The conclusion reached must square with the facts. Science does not recognize rumor or mere guesswork. If the true scientific attitude is maintained, objective, factual evidence always supplants authority.

The laboratory manual should not be regarded as a handbook of formulas and directions that are to be slavishly followed. It is designed merely as an aid to the student. The laboratory manual points out important structures to be seen; it formulates certain problems and suggests ways for solving them; it suggests certain drawings that are designed to be helpful in recording facts; and it proposes questions that may lead to correct conclusions derived from the facts observed or data obtained through experiment. The thoughtful student will see many more things and frame many more problems than those suggested in the manual.

The student is urged to approach his laboratory studies with the vigorously curious mind of the investigator. The laboratory exercise should not be considered as a compulsory job but as an opportunity to find out more about plants and animals, and how they carry on their work. Here the student may "ask the organism" all manner of questions and receive first-hand answers. Here credulity and superstition are replaced by dependable knowledge. Here is the place to develop the investigative spirit, and to cultivate an open and tolerant mind.

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CONTENTS

A NEW MANUAL FOR THE BIOLOGY LABORATORY

STUDENT EQUIPMENT

Each student should have the following equipment for the course in general biology.

Furnished by the student:

1 Laboratory Manual
1 dissecting set consisting of
  2 dissecting needles
  1 scalpel
  1 pair of dissecting forceps
  1 pair of scissors
1 hand lens
1 ruler graduated in millimeters (celluloid preferably)
1 soft lead pencil
1 eraser with bevelled ends (*not art gum*)
3 pieces of emery paper or sandpaper
3 Bristol covers and ruled note paper
1 yard of cheese cloth
1 hand towel
1 large manila envelope
1 box of colored pencils

GENERAL DIRECTIONS

NOTES

1. **First, study material carefully, then write your notes. Write either with ink or a soft lead pencil. Answer all questions by a sentence; never by "yes" or "no."** All questions must be preceded by the question number, as, 1, or 27. Be clear and concise. Do not repeat what your instructions have already told you.

2. Include in your notes only what you have observed in the laboratory. Extraneous matter learned elsewhere should be inclosed in brackets.

3. Keep notes ready for inspection at any time.

DRAWING

1. Keep a sharp point on your pencil always.

2. Make sketches only after all questions have been answered.

3. Study the object and sketch lightly. Finally, finish the drawing with drawing pencil. Make the lines sharp and do not attempt to shade.

4. Draw what you see, not what you think you ought to see or what you hope to see.

5. Omit no details unless so directed.

6. Do not make the drawing too small; a drawing too large is always better than one too small.

7. Draw all index lines with a ruler and write the name of the structure **horizontally** from the end of the line.

8. Number the plate at the upper right-hand corner with a Roman numeral and write your name in the lower right-hand corner. **Write the title of each figure underneath it.**

CORRECTIONS

Laboratory drawings and notes should be kept in readiness for inspection at any time. The following symbols are suggested for use in correcting laboratory reports.

s—misspelled
E—English
?—indexing wrong or incorrect answer
inc—drawing not fully indexed
no—questions or descriptions lacking

THE MICROSCOPE

STRUCTURE OF THE MICROSCOPE

The compound microscope is a complicated, delicate mechanism which must be handled carefully. Never try to repair the microscope; always consult an instructor or an assistant.

The microscope consists of the following parts (Fig. 1, p. 51):

Ocular or eyepiece. This is a small removable tube at the top.

Body tube. This is the main tubular portion of the microscope.

Draw tube. This is a tube located within the body tube.

Revolving nosepiece. This is attached to the lower end of the body tube.

Objectives. There are usually two or three of these attached to the nosepiece.

Rack and pinion or **coarse adjustment.** The milled wheels used to move the body tube up and down.

Fine adjustment. A smaller milled wheel whose use is the same as the above.

Arm. This is the support of the parts described above and **the proper place to hold the instrument when moving it.**

Stage. This is the platform upon which rests the object to be examined.

Mirror bar and **mirror.** These are found beneath the stage.

Condenser and **iris diaphragm.** These are also beneath the stage, and are used for regulating light.

Pillar. This is the post rising from the **horseshoe base.**

Study the microscope carefully and learn its parts. In Fig. 1, page 51, after the name of each part, state its use briefly.

USE OF THE MICROSCOPE

Follow carefully the directions for using the microscope and for focusing. Always:

1. Focus **upward** when looking into the microscope; never downward.
2. Clean an objective or an ocular with lens paper; never with a handkerchief or cloth.
3. Keep the microscope clean.

(*a*) Strip off a piece of the thin transparent covering of the lower surface of a leaf (the **epidermis**); place it in a drop of water on a glass slide, stain as directed by instructor to show the **nucleus,** and cover with a cover glass. (In the first work with the microscope, the instructor may prefer to use slides on which a letter or a figure has been mounted.) Using the 4x or 5x ocular and 16-mm. objective, adjust the mirror until the field of the microscope is a clear white circle. Then place the slide with the mounted piece of leaf epidermis (or letter) as near the center of the circular opening in the stage as possible. With the coarse adjustment bring the objective as close as possible to the slide without touching it. Now, looking through the ocular, carefully focus upward with the coarse adjustment until you can see the object.

If leaf epidermis is used, note the units of which the object is composed. These are **cells.** Each contains a dense mass, the **nucleus** (plural, **nuclei**), which is usually visible. The remainder of the contents of the cell, besides the nucleus, is to all appearances nearly structureless and is known as **cytoplasm.** Both nucleus and cytoplasm are composed of **protoplasm.** The boundary of each of these cells is the **cell wall.** Observing either the epidermis or the letter on the slide, answer the following questions:

1. Move the slide to your right on the stage; in what direction does it appear to move when observed through the microscope?
2. Reverse the motion and note the direction in which the object appears to move.
3. Now move the slide away from you on the stage; in what direction does it seem to move?
4. Reverse and note the direction of movement.
5. Consult the following table of magnifications and determine how much the object is magnified.

MAGNIFICATION TABLE

TUBE LENGTH, 160 MM. IMAGE DISTANCE, 250 MM.

Objectives mm.	Initial Magnification	OCULARS								Objectives mm.
		4x	5x	6x	8x	10x	12x	15x	20x	
48	2.2	8	11	13	18	22	27	33	44	48
40	2.8	11	14	17	22	28	33	42	56	40
32	4	16	20	24	32	40	48	60	80	32
30–22	2–4.5	4–9	5–12	8–19	10–24	15–35	18–43	20–48	30–70	30–22
25.4	6	24	30	36	48	60	72	90	120	25.4
16	10	40	50	60	80	100	120	150	200	16
12	15	60	75	90	120	150	180	225	300	12
8	20	80	100	120	160	200	240	300	400	8
5	36	144	180	216	288	360	432	540	720	5
4	44	176	220	264	352	440	528	660	880	4
3	60	240	300	360	480	600	720	900	1200	3
1.8	95	380	475	570	760	950	1140	1425	1900	1.8
1.5	109	436	545	654	872	1090	1308	1635	2180	1.5

(Permission of Spencer Lens Co., Buffalo, N. Y.)

In the upper circle on page 53, Fig. 2, draw a group of three or four adjacent cells (or the outline of a letter). A sharp outline of the cells and their nuclei should be drawn in proportion to the size of the circle. As previously directed, index carefully the **cytoplasm, nucleus,** and **cell wall.**

Replace the 4x or 5x eyepiece with an 8x or 10x eyepiece.

6. Now observe the epidermis (or the letter). What change do you note?

Focus the microscope carefully until the object is clearly seen and then turn the revolving nosepiece until the 4-mm. objective is in place. When the objective is in position a faint "click" is heard. Using the fine adjustment, focus the microscope until you can see the cells clearly.

7. What is the shape of the epidermal cells?

Move the slide about on the stage and examine the object more closely. Other cells, green in color, called **guard cells,** may be found. These regulate the size of a little opening between them, the **stoma** (plural, **stomata**). Through the stoma, gases enter and escape from the leaf.

8. What is the shape of a guard cell?
9. How many times are the cells magnified?

In the lower circle on page 53, Fig. 3, on a scale proportional to the size of the circle, draw a portion of the epidermis showing **guard cells, stomata,** and the **epidermal cells** surrounding them.

THE STUDY OF CELLS

(*a*) Proceed as above to mount some epidermis of the scale leaf of an onion. In peeling off the epidermis, care must be taken to avoid including underlying cells, since otherwise two different layers of cells may be seen. Using the 16-mm. objective and the 8x or 10x ocular, examine the epidermis under the microscope. (This combination of objective and ocular is the best for most of the work in this course.)

10. What differences do you notice between the epidermis studied previously and the epidermis of the onion?

How much are the cells magnified?

At the top of page 55, Fig. 4, draw several adjacent cells.

(*b*) Using a scalpel, scrape lightly the inside of the cheek. Place the scrapings in a drop of water on a slide, add nuclear stain and cover glass, and examine with the microscope, trying out different light intensities.

On page 55, Fig. 5, draw a group of three or four cells. Make the drawing of each cell about 15 mm. in diameter. A neat outline of the cells and their nuclei will suffice. Index **nuclei** and **cytoplasm.**

(*c*) Examine a slide of the stained blood of a frog or salamander. On page 55, Fig. 6, draw in outline a red corpuscle showing the nucleus. This is one of the corpuscles which gives the blood its red color.

(*d*) Observe the cells (any material showing cell structure) shown under the demonstration microscopes.

11. What conclusion do you draw concerning the make-up of living things, both plant and animal?

(*e*) On page 55, Fig. 7, draw a hypothetical cell to show its dimensions and essential parts. Make the drawing at least 4 cm. long.

(*f*) *Movements of protoplasm.* Under the demonstration microscope there has been mounted a young living leaf of *Elodea.* Under high magnification, look for movements of the protoplasm inside some of the cells. If movements of the protoplasm are not observed at first, they will usually begin after a few minutes. This form of movement is known as "rotation" or **cyclosis.**

12. In what region of the cell does cyclosis occur?

13. Compare the direction of rotation in adjacent cells.

On page 55, Fig. 8, draw an outline of the cell at least 5 cm. long and indicate by arrows the direction of rotation.

(*g*) *The activities of a single-celled organism* (*Ameba*). The ameba, one of the simplest animals, is made up of a single cell. A study of the ameba will show many of the life activities of living protoplasm. Using a medicine dropper, procure some material from the culture. Place it on a slide and cover it with a cover glass. Study under low power of the microscope with most of the light cut off. Look for an irregular somewhat granular object which has a narrow clear border around it. Watch it closely to see if it changes shape. Then ask the instructor to check your finding. If you have an ameba, observe the projections, **pseudopodia,** which push out from its surface and note the flow of protoplasm into these pseudopodia.

14. What is the type of movement where pseudopodia are formed?

On page 57, Fig. 9, draw several outline sketches of the ameba to show its change in shape and its direction of locomotion.

Now use the high power and observe the clear outer border known as the **ectoplasm.** The granular central mass is the **endoplasm.** Note the more opaque **food granules** and **food vacuoles** present in the endoplasm. These are the sources of energy for the ameba.

15. How would the single-celled ameba secure oxygen and throw off carbon dioxide?

In the endoplasm may be seen a small spherical clear spot which disappears at intervals. This is the **contractile vacuole,** whose function is to eliminate excess water from the animal.

16. How many times does the vacuole contract in a minute?

On the prepared slide on the demonstration microscope, observe the **nucleus.**

On page 57, Fig. 10, make a sketch of the ameba and show the structures just mentioned.

COLLOIDAL ACTIONS

Gelatin sol. Place approximately 1 gm. of powdered gelatin in each of two test tubes. Add to one tube 10 cc. of distilled water and let the tube stand for about an hour at room temperature.

17. Observe and explain.

Place the tube in a beaker of water and heat to boiling. Now set the tube aside to cool. Observe later.

18. Describe the results.

To the second tube add about 10 cc. of hot water and continue heating.

19. What is the result?

PLANT STRUCTURES

LEAVES. THE ORGANS OF FOOD MANUFACTURE

(*a*) Study the leaf furnished. Note the **petiole,** the stalk-like structure by which it is attached to the twig. The petiole continues through the broad expanded portion of the leaf as the **midrib,** from which may branch other structures at more or less regular intervals, the **veins.** The expanded portion of the leaf is known as the **blade** or **lamina.**

On page 59, Fig. 11, draw or trace a leaf to show the above structures.

(*b*) Recall the structure of the epidermis of the leaf as described on page 2.

20. What is the function of the epidermis?

21. What is the function of the guard cells and stomata?

With a razor blade make four or five thin cross sections of the leaf. Mount on a glass slide in water and observe a favorable section under the microscope. Notice the clear outer layer of cells, the **epidermis.**

22. What different kinds of cells are found in the epidermis?

Underneath the **upper epidermis** notice the regular layer of elongated green cells, the **palisade cells.** Imbedded within these cells are rounded green bodies, the **chloroplasts.** Between the palisade cells and the lower epidermis is a region of loosely arranged cells, the **spongy tissue.** Palisade cells and spongy tissue taken collectively make up the **mesophyll** of the leaf. In the spongy tissue there are numerous **air spaces** which communicate with each other. In certain portions of the section, note areas of thick-walled cells, the outer layers of the **veins.** These heavy-walled cells form the **bundle sheath.** Within this may be seen, in a favorable section, the large, angular cross sections of thick-walled ducts collectively called **xylem.** Small, angular cross sections of thin-walled cells may be found below the heavy-walled xylem ducts. These are the cut ends of the **sieve tubes** of the **phloem.**

23. What is the function of the xylem?

24. What is the function of the phloem?

On page 59, Fig. 12, complete the drawing of the cross section of the leaf showing the parts observed.

Collect and mount fifteen different types of leaves. Name the plant to which each leaf belongs, the general shape of the leaf, and the type of tip, base, and margin. Hand in the collection at the next laboratory period. (See Fig. 13.)

STEMS. ORGANS OF TRANSPORTATION

(*a*) Study the stem of a buckeye or other dicotyledonous plant furnished. (A dicotyledonous plant is one in whose seed there are two seed leaves called cotyledons.) On the one end will be found the swollen club-shaped **terminal bud** protected by the overlapping **bud scales.** Note the ring of narrow scars around the stem in one or more places; these mark the places where the scales of the terminal buds of previous seasons were attached.

25. What was the greatest amount of growth (in centimeters) made by the twig in any one season?

26. What was the least amount of growth (in centimeters) made by the twig in any one season?

27. How old is the twig?

Note the structure of the **bark.** Note the **leaf scars.** In the horse chestnut and buckeye, the leaf scars are horseshoe-shaped but the outline of the scar is characteristic of each species. Within the scar observe a number of dots, the **ends of the vascular bundles** made up of phloem and xylem and continued into the leaf as the veins.

Note the small swellings or knobs, the **lateral buds.** These arise at the **nodes** and the distance from one to the other is an **internode.** Small roughened spots or corky patches, the **lenticels,** will be found on the bark. Their function is the same as that of the stomata of the leaf.

28. How are the leaves arranged on the twig; that is, are they opposite or alternate?

29. What is the function of the lenticels?

On page 63, Fig. 14, complete the drawing of a portion of a twig.

(*b*) Using a sharp scalpel, or razor blade, cut several extremely thin cross sections of some herbaceous stem (bean, sunflower, geranium, coleus, etc.), and selecting one of the thinnest sections, study it under the low power of the microscope. Note the outside layer of **epidermal cells.** Beneath the epidermis is a green tissue, the **cortical parenchyma.** Just inside the parenchyma is an intermittent ring of oval or rounded areas with little holes appearing in each one. These areas are the **cut ends of the vascular bundles** and the holes are the cross sections of the vessels. The ring of vascular bundles surrounds a central area of parenchyma, the **pith.** The cortical parenchyma and pith are continuous between the bundles in what are called the **primary pith rays.** This is the general plan of structure of the herbaceous dicotyledonous stem.

On page 63, Fig. 15, sketch, in outline only, the regions of the herbaceous dicotyledonous stem just studied.

Study carefully the cross section of the basswood or other woody dicotyledonous stem furnished and try to identify all the tissues. After you have completed this study, label accurately in the drawing on page 65, Fig. 16, the following: **cork, cork cambium, cortical parenchyma, pericyclic fibers, phloem, cambium, xylem, pith rays,** and **pith.** Note that cambial tissue is present in each vascular bundle. This is called an **open bundle.**

30. What is the relation of the cambium to the phloem and xylem of the vascular bundle?

31. How old was the stem from which the section was cut?

32. Tabulate the tissues of the stem you have studied and record their functions.

(*c*) Study the external appearance of a monocotyledonous stem. (A monocotyledonous plant is one in whose seed there is but one seed leaf or cotyledon.)

Identity **nodes** and **internodes.**

33. How does this stem externally differ from the buckeye stem?

Study a cross section of the corn stem. Note the hard outer rind of the stem composed of thick-walled cells forming a hard tissue, the **sclerenchyma.** The bulk of the tissue of the stem is **parenchyma** or **pith.** Scattered through the pith are numerous opaque spots, cross sections of the

ascular bundles. These vascular bundles contain no ambium and are therefore known as **closed bundles.**

Complete in diagrammatic outline only the drawing of he cross section of the corn stem on page 67, Fig. 17.

Index accurately the tissues of a vascular bundle of the orn stem, shown in the drawing on page 67, Fig. 18.

34. What differences do you note between the stem of a nonocotyledonous plant and the stem of a dicotyledonous plant? Answer in detail.

(*d*) *Underground stems.* Some stems are developed underground and have special modifications for storage or other functions. Examine a portion of the rhizome of an iris. Note the **growing point** or **bud** from which the aerial stem will arise next season. Observe also the scars at which the aerial stems of previous seasons broke away. **Bundle scars,** marking the ends of vascular bundles, may be seen within the stem scars. Note the **scale leaves,** mere ridges on the rhizome. These occur at **nodes,** with **internodes** between. **Adventitious roots** may be observed, attached to the rhizome at irregular intervals.

On page 69, Fig. 19, sketch a rhizome and label the distinctive features.

Now study the tuber of a potato. Note the "eyes" or **buds,** the "eyebrows" or **scale leaves,** and the stalk which was the attachment to the aerial stem. Cut the tuber through transversely and note the **vascular cylinder.**

35. How could you prove that a potato tuber is a stem and not a root?

On page 69, Fig. 20, sketch a tuber and label parts.

Cut through the bulb of an onion longitudinally. Note the **stem,** which is reduced to a mere plate, surrounded by a coating of fleshy, overlapping **leaf bases.** Observe also the **roots** and the **bud** or **growing point.**

Sketch on page 69, Fig. 21, a section of a bulb and label the parts mentioned.

Observe the vertical section of the corm of a gladiolus. Note the dry **leaf bases,** the **stem** packed with stored food, the **roots,** and the growing point or **bud.**

36. How do corms differ from buds?

Sketch on page 69, Fig. 22, a section of a corm and label parts.

ROOTS. ORGANS OF ABSORPTION, TRANSPORTATION, AND STORAGE

(*a*) Examine a young seedling and note the **root hairs.**

37. Upon what region of the root are they best developed?

38. Are they absent from any part of the root?

Observe some young seedlings that have been carefully removed from the soil. Note the soil particles clinging to the root hairs.

39. Of what advantage to the plant are root hairs?

(*b*) Cut a median longitudinal section through a fleshy root, such as a carrot or parsnip. Observe the **central cylinder,** the **cortex,** and the branch roots or **secondary roots.**

40. At what region in the root do these secondary roots arise?

On page 71, Fig. 23, sketch, in outline only, a longitudinal section of a root and label the parts indicated above.

41. What different functions can you mention for such roots as carrots, parsnips, and turnips?

(*c*) Using a prepared slide, study a cross section of such a root as that of the meadow buttercup. Note the outer layer, the **epidermis.**

42. Are any root hairs present?

43. What relation do these have to the other cells of the root?

Within the **epidermis** is the **cortical parenchyma** which extends to the **endodermis.** Just inside the endodermis is the **pericycle,** the tissue in which the secondary roots arise. Within the pericycle are the **xylem** and **phloem.** There is usually no pith; the xylem fills in the central space with three or more tapering arms extending out to the pericycle. The phloem fills in the space between these arms except that space, occupied by the cambium, lying between the xylem and the phloem. As the root grows older, the cambium forms a continuous ring, and the subsequent growth of phloem and xylem becomes precisely the same as that of the stem.

After completing the study of the slide, label accurately the drawing on page 71, Fig. 24.

Tabulate the tissues of the root and record the functions of each.

(*d*) (Optional.) Collect, mount on cardboard, and hand in at the next laboratory period, a specimen of each of the following forms of roots: fleshy root; fibrous root; aerial roots; tap roots; aquatic roots; and adventitious roots.

FOOD MANUFACTURE

ABSORPTION OF RAW MATERIALS

(*a*) *Diffusion.* (*Demonstration by instructor.*) Place some ether or other aromatic liquid in an open dish in the room and note the time required to detect the odor in various parts of the room. Drop a crystal of copper sulphate into a glass of water and note rapidity and nature of diffusion.

44. In general, do gases diffuse more rapidly than solids and liquids?

(*b*) *Osmosis.* (*Demonstration experiment by instructor.*) This is to be written up outside the laboratory and the report completed before the next laboratory period.

Fill the cup parts of two thistle tubes with a strong solution of sugar or salt or syrup solution. Tie a piece of bladder that has been soaked in water over the mouth of each cup. Immerse the cup in water, adding a little formalin to the water if sugar is used. Mark off with wax pencil spaces 2 cm. apart on the glass tube. Make hourly observations and record results.

45. Has either substance passed through the membrane?

46. Explain how osmosis takes place.

On page 73, Fig. 25, sketch the apparatus. This may be done outside the laboratory period.

47. What is the difference between diffusion and osmosis?

(*c*) *Osmosis.* (Work with your partner.) Using the top (or bottom) of a large carrot, hollow out one end and fill with salt. Fill the other half, similarly prepared, with sugar.

48. Record any changes that take place, giving reasons for them.

(*d*) (*Optional or demonstration.*) Cut some small cubes from the root of a beet and wash thoroughly. Place some of the cubes in cold water and allow them to remain there for several minutes. Boil some water in a small beaker, put a few of the cubes in the water, and continue boiling for a few minutes.

49. Record and explain observations.

(*e*) (*Demonstration experiment by instructor.*) Partially inflate two small rubber balloons with air, and tie the neck of each securely so the air cannot escape. Suspend one of these balloons in a wide-mouthed liter bottle full of air. Suspend the other balloon in a similar bottle containing CO_2 which may be generated or obtained from a CO_2 tank. Stopper both bottles tightly and seal with paraffin.

50. Observe this experiment at the end of the period and for 24 hours later. Record and explain the results.

(*f*) *Turgor in an artificial cell.* (*Demonstration experiment by instructor.*) Fill a test tube with a strong solution of salt. Care must be taken to have the tube completely filled and all air bubbles removed. Tie a piece of animal membrane soaked in water over the mouth of the tube. Lay the tube in a dish of water. After the membrane shows considerable turgidity, place the tube in a vertical position, membrane up, and then quickly pierce the membrane with a needle.

51. Record and explain the results obtained.

(*g*) *Plasmolysis.* Mount a living green leaf of *Elodea* or some of the epidermis of an onion scale, and examine under the microscope. Note carefully the relative position of cell wall and cell contents. Using a filter paper, draw off the water from beneath the cover glass and add a 10 per cent solution of potassium nitrate or sodium chloride. After a short time note the result.

52. What conclusions can you draw from this experiment as to the relative permeability of cytoplasm and cell wall to water and to salt solution?

53. Explain why it is incorrect, in speaking of plasmolysis, to say that salt solution draws the water out of the cell.

TRANSPORTATION OF RAW MATERIALS

(*a*) (Work with partner.) Fill two test tubes nearly full of water. To one add a small amount of powdered eosin; to the other add some powdered carmine. By shaking or stirring, mix the contents of each tube. The eosin goes into solution but the carmine forms only a suspension in the water. Place a seedling of jewelweed or other clear-stemmed plant in each tube so that the roots will be in the liquid. After 5 or 6 hours, or more, examine the plants to determine whether absorption of the eosin and carmine has taken place.

Cut and examine some cross sections of the stem of the plant placed in the eosin solution.

54. Is the solution or stain equally diffused through the stem or is it confined to certain areas? Explain.

55. Has the liquid passed into the leaf?

56. What regions are most intensely stained? Why?

Cut some cross sections of the plant placed in the carmine suspension.

57. Is there any trace of the carmine in the stem? Why?

THE FOOD-MANUFACTURING PROCESS. PHOTOSYNTHESIS

(*a*) (*Instructor's experiment.*) Place a plant in darkness for at least 24 hours. Then place a light screen on a leaf and leave the plant in a well-lighted place for 2 hours or more. Remove the leaf from the plant and kill it by boiling in water. Then extract the chlorophyll with alcohol. Now place the leaf in an iodine solution.

58. Describe and explain results.

(*b*) (*Optional.*) Sketch a variegated leaf of *Coleus*, part of the blade of which is white. Use crayon to show the green area. Place the leaf in hot water and allow it to remain until the red color disappears. Make another sketch of the leaf. Place the leaf in alcohol and heat to remove the chlorophyll. Sketch the leaf again. Now treat the leaf with iodine solution and sketch again. Color all the sketches.

59. Explain the results of this experiment.

(*c*) (*Optional.*) Remove two similar leaves from a plant that has been kept in the dark for two days. Place the petiole of each leaf in a bottle of water. Now set one of the bottles in a solution of potassium hydroxide (an absorbent of CO_2) that fills a large beaker to a depth of 1 cm., and cover the bottle with another smaller beaker. Do the same with the other bottle, substituting water for the

tassium hydroxide. Expose them to several hours of nlight and then test for starch.

60. Explain the results of this experiment.

(*d*) (*Optional.*) Using a plant such as *Coleus* or *Nasturm*, that has been kept in the dark for two days, cover lf the lower surface of several leaves with vaseline and en place the plants in sunlight for several hours. Now nove all traces of the vaseline, extract the chlorophyll, d test for starch.

61. Explain the results of this experiment.

62. What structural modifications of the leaf must be pt in mind when selecting a plant for this experiment?

(*e*) (*Demonstration.*) If a spectroscope is available, amine a solution of chlorophyll extracted from a leaf by eans of alcohol.

63. What light rays are absorbed?

Summary. (This may be completed outside the laboratory.)

64. How and by what tissues are raw materials conveyed the leaf?

65. How and by what tissues are foods synthesized?

66. What proof have you that the vascular bundles of ot, stem, and leaf are continuous systems?

67. Describe photosynthesis.

FOOD STORAGE AND FOOD TESTS

(*Demonstration experiments by the instructor or student oups.*)

Test the foods furnished for the various substances listed cording to the following directions:

Starch test: Add a few drops of dilute iodine solution to e substance to be tested. If a blue color results, this indites that starch is present.

Glucose test: Put some of the substance to be tested in a st tube and add an equal amount of Benedict's solution ehling's solution may be used.) Heat to the boiling int. A greenish yellow or red precipitate is formed if ucose is present.

Test for fats and oils: Rub the substance to be tested on a ece of paper and hold the paper to the light. If the paper ows a translucent, waxy spot, oil or fat is present.

Sudan III may be used as a test for fats. This imparts a red color to the fat.

Protein or nitrogenous food test: Place some material to be examined in a test tube with a few cubic centimeters of concentrated nitric acid and heat *gently*. Note any color that appears. Rinse with water to wash off acid. Add a little ammonia and note any change in color. If the color changes from lemon-yellow to orange, protein is present.

Test for water: Weigh the material to be tested. Warm gently until it is thoroughly dry. (Use an oven if one is available.) Do not overheat. Reweigh. Calculate the amount of water present in percentage of original weight.

Foods are stored in various regions of plant and animal bodies. Applying the above tests, record the results obtained in testing the materials furnished you in the following table on page 75, Fig. 26. In tabulating results, use the following symbols: Lacking (−), trace (+), medium amount (++), large amount (+++).

68. From your observations, state what organic and inorganic nutrients are present in plant and animal matter.

69. Of what advantage to the life of an organism is it that seeds and eggs are rich in food materials?

TESTS FOR OTHER PLANT SUBSTANCES (OPTIONAL)

Cellulose test: Place a few cotton fibers on a slide; add a drop of iodine and a cover glass. Note color of fibers under low power. Now place a small drop of 75 per cent sulphuric acid on the slide along the edge of the cover glass and note the change of color as the acid comes in contact with the fibers. Cotton fibers are almost pure cellulose.

Lignin test: Place a thin section of the wood of a match on a slide; add a drop of phloroglucin solution and a cover glass. After a few minutes place a drop of concentrated hydrochloric acid at the edge of the cover glass. Note the color of the walls of the wood cells. These walls consist largely of lignin.

Suberin or cutin test: Place a very thin section of cork on a slide and add a drop of Sudan III solution. Put on a cover glass and let stand for 20 minutes. Wash off the dye with 50 per cent alcohol. Now add a drop of glycerine and a cover glass. Note the color of the cell walls. Cork walls consist largely of suberin.

DIGESTION

THE PROCESS OF DIGESTION. DIGESTION IN PLANTS

(*a*) Place a thin slice of potato on a slide; add a drop of lphuric acid and let stand a few minutes. Under the low wer of the microscope observe the changes that are tak- g place. When the starch grains are broken down, add a rop of potassium hydroxide to neutralize the acid. Then st for sugar.

70. Record your results.

(*b*) Fill each of three test tubes about one quarter full of warm water. Label *A*, *B*, and *C*. To tube *A* add 10 drops of boiled starch paste and test with iodine immediately. To tube *B* add 10 drops of boiled starch paste and 10 drops diastase solution. Test with iodine after half an hour. To tube *C* add 10 drops of boiled starch paste and 10 drops diastase solution. Test with Benedict's solution after half an hour.

(c) *Examination of starch grains.* Make very dilute suspensions of potato, corn, and wheat starch in water. Add a drop of each suspension to a glass slide and study under the microscope.

71. How do you account for the marking on the grain?

72. How do the grains differ with respect to size and shape?

On page 75, Fig. 27, make sketches of the grains of each kind of starch.

(d) *Hydrolysis of a polysaccharide.* Make up a solution of 25 cc. of starch paste. Add 2 cc. of hydrochloric acid. Then heat for 10 minutes in a water pan until the solu clears.

73. How do you explain the clearing of the solution?

Neutralize with sodium hydroxide and then test a f drops of the solution with iodine.

74. Is there any starch present?

Now test the solution with Fehling's solution or Be dict's solution.

75. What reaction do you get?

76. How would you explain this reaction?

DIGESTION IN ANIMALS

THE MECHANISM. DIGESTIVE TRACT OF THE FROG, A TYPICAL VERTEBRATE OR BACKBONED ANIMAL

(a) *The buccal cavity and pharynx.* Open the mouth of a preserved frog to the widest extent, cutting through the angles of the jaws if necessary. The following structures should be seen and identified:

upper lip fold

maxillary teeth, a continuous curving row of teeth in one of the jaws (See skeleton of a frog.)

vomerine teeth, two patches of them (on "roof" of the mouth)

internal or **posterior nares,** two openings which lead into the nasal passages

openings of the Eustachian tubes which lead to the ears

tongue (Note its shape, size, and attachment.)

77. How does it differ from your tongue?

Turn the tongue forward and feel the floor of the mouth behind the tongue. In the median line there is a circular hardened elevation, the **laryngeal prominence,** which bears in its center an elongated slit, the **glottis.**

78. Where does the glottis lead?

The mouth opens into the **buccal cavity** which merges with the more posterior cavity, the **pharynx.** At the back of the pharynx, the roof and floor converge to a large opening, the beginning of the **esophagus.**

79. Note the position of the glottis and the beginning of the esophagus. Assuming that the same relation exists in man, how would you account for a man's choking when eating or drinking?

Complete the drawing on page 77, Fig. 28, showing the buccal and pharyngeal cavities.

(b) *The alimentary canal.* Place a preserved frog upon its back in a dissecting pan, with the head farthest from you. Cut through the skin and muscles of the abdomen to the left of the midventral line of the body. Then with the scissors make an incision the length of the abdomen, taking care to cut no deeper than necessary. Continue the incision through the bony pectoral girdle, that is, the median ventral region between the forelegs. Make two lateral cuts just back of the forelegs and two lateral cuts just anterior to t hindlegs. Now turn back the abdominal walls and p each wall to the dissecting pan, exposing the **viscera** or i ternal organs which lie in the large **body cavity** or **coelo** The viscera (the stomach, liver, intestines) are covered w the **visceral peritoneum,** whereas the inside body wall lined with the **parietal peritoneum.**

80. What is peritonitis?

Like the plant, the frog is made up of a number definite structures called **organs,** each of which has a defin function to perform. All the organs which aid in performi the same function are grouped together, forming a syste The organs constituting one system may be all alike or m be different. In general, most animals have ten systen the **skin and its derivatives, skeletal, muscular, digestiv circulatory, respiratory, excretory, reproductive, nervou** and **sensory systems.**

The parts of the digestive system are: the **mouth cavi** or **buccal cavity, pharynx, esophagus, stomach, small inte tine, large intestine,** and **digestive glands.** The esopha lies dorsal to the heart. Push the organs carefully to o side and see if you can identify the **esophagus.** It pas into the elongated **stomach,** a conspicuous white organ o the left side of the body, dorsal to the brown-colored orga the **liver.** Note the round green **gall bladder** between t lobes of the liver.

81. What is the function of the gall bladder?

(If the animal is a female, the large **ovaries** and **oviduct** voluminous lobed black and white masses, will obscure t rest of the abdominal viscera and may be carefully remov from the left side.) From the end of the stomach, trace t **small intestine,** a coiled tube, to its rather abrupt enlar ment into the **large intestine** or **rectum.** Note that the in testine as well as the other organs in the abdominal cavi are attached or suspended by thin folds of tissue c **mesenteries.** The first part of the small intestine is c the **duodenum.** Note the constriction of the small int where it leaves the stomach. This is the regulatory dev or **pyloric valve.** Through the **anus,** the **rectum** opens i the **cloaca,** which in turn opens to the exterior through t **cloacal aperture.** The entire tube from mouth to anu

e **alimentary canal.** Associated with the alimentary nal are two digestive glands, the **liver,** already mentioned, d the **pancreas.** Leading from the gall bladder to the odenum is a small tube, the common **bile duct.** The ncreas is a yellowish, very irregular body, lying in the esentery which extends between the liver, the small intes- ne, and the stomach. In the mesentery near the junction the small and large intestines, note the dark reddish herical body, the **spleen.** The spleen is *not* a digestive gan.

82. What is the function of the liver?

83. What is the function of the pancreas?

Study the model of the human digestive system and com- are it with that of the frog.

On pages 79 and 81, Figs. 29 and 30, index the anatomy f the digestive systems.

Your frog is to be used in further study. Using a soft lead encil, write your name clearly on the label furnished and ttach it to the frog, as directed by the instructor.

HISTOLOGY (TYPES OF ANIMAL TISSUES)

You have already seen that the seed plant is made up of issues such as parenchyma, phloem, and xylem. Moreover, ou have observed these tissues combined in various ways o form the organs of the plant, viz., leaf, stem, and root.

We have just completed the study of the gross anatomy f the alimentary system of an animal. This system is made p of organs. The animal organism, like that of the plant, s made up of organs which, in turn, are composed of various types of tissues, some of which are found in the alimentary tract.

In order to obtain a better appreciation of the structure of animals, some knowledge of their tissues is worth while. Recall from your text that there are four general types of tissue: **epithelial** (squamous, columnar, stratified), **contractile** (non-striated or voluntary muscle, striated or voluntary muscle, cardiac or heart muscle), **sustentative** (connective tissue, cartilage, bone, fat, and vascular), and **nervous.**

(*a*) *General arrangement of tissues in the frog intestine, an organ.* Use 8x or 10x ocular and low-power objective and study the stained cross section of the frog intestines. This study will serve not only to acquaint you with certain types of tissues, but also to show how tissues may be arranged to form organs. In general the wall of the intestine consists of four coats. Beginning next to the cavity, we may identify them as follows:

The **mucous layer** or **mucous membrane** is the innermost layer, containing numerous nuclei. It is thrown up into folds and is rather clearly differentiated from the next layer.

The **submucous layer** or **submucosa** is a broad band of connective tissue containing frequent spaces and extending up into the folds of the mucosa.

The **muscular layer** makes up most of the remainder of the intestinal wall. This layer is made up of smooth muscle cells bound together by connective tissue. Two main regions or layers may be identified: a **circular muscle layer** (the inner layer) in which the muscle cells run in a circular direction around the intestine, and the **longitudinal muscle layer** (the outer layer) in which the muscle cells run in a longitudinal direction. In cross section, only the cut ends of the muscle cells will be seen. This layer also contains a considerable quantity of connective tissue.

The **serous coat** or **visceral peritoneum** is a very thin layer of **squamous epithelial cells** covering the outside of the intestine and cannot be seen under the low power.

84. What is the function of these two layers of muscle?

Index accurately the drawing of the cross section of the intestine on page 83, Fig. 31.

(*b*) *Tissues. Epithelium.* 1. *Columnar epithelium.* Select a favorable place in the cross section of the intestine where the mucous membrane is cut parallel to the long axes of its cells. The best places are generally at the bottom of the folds. Study this with the high power. The mucous layer is the lining epithelium of the intestine and is made up of a single layer of tall **columnar cells,** each extending from the cavity of the intestine to the underlying connective tissue. The outlines of the cells are frequently difficult to see. In the lower part of each cell there is a large oval **nucleus.** In many of the epithelial cells are goblet-shaped cavities which are filled with mucus. These are called **goblet cells.**

On page 85, Fig. 32, sketch three or four adjacent cells.

2. *Squamous epithelium.* Now study the outer layer or very border of the intestine. This is the serous coat or visceral peritoneum. It is a thin membrane made up of flat epithelial cells, very similar to those scraped from the inside of the cheek in one of the early experiments (p. 3). Because of the manner in which the intestine has been cut, you will see only the cut edges of the cells; hence they appear only as a thin line. Under the high power, thickened areas of the cells may be seen containing darkly stained **nuclei.**

On page 85, Fig. 33, sketch several cells of squamous epithelium.

3. *Stratified epithelium.* Examine a prepared slide of stained frog skin. Note that the outer layer, the **epidermis,** is made up of compact layers of cells whose nuclei are close together. Stratified epithelium usually covers surfaces where there is abrasive action.

85. Why would you think stratified epithelium is well adapted for such locations?

86. Name three places in your body where you might expect to find stratified epithelium.

On page 85, Fig. 34, sketch the stratified epithelium of frog skin.

(*c*) *Tissues. Connective or Supporting.* 1. *Connective tissue proper.* Study the submucous layer or the submucosa, which is found under the columnar epithelium making up

the mucosa. The submucosa is made up of connective tissue in which there may be found lymph vessels and cross sections of blood vessels. Often there may be seen one or more blood corpuscles in the sections of the blood vessels.

87. Do you find any cells or nuclei among the connective tissue fibers?

On page 85, Fig. 35, sketch as accurately as possible a section of the submucosa of the intestine as it appears under the *highest possible* magnification of the microscope.

2. *Cartilage.* Cut a thin slice of living cartilage from the frog, or use the prepared slide of cartilage provided. Note that the cartilage consists of a rather clear, firm material called the **matrix.** Here and there in the matrix are small rounded cavities, the **lacunae,** in which are one or two **cartilage cells.** These cells secrete the matrix.

On page 85, Fig. 36, sketch as accurately as possible a section of the cartilage to show the above details.

3. *Bone.* Study a prepared slide of a section of bone. The bone matrix is made hard and strong by the deposition in it of certain mineral salts. (In preparing this section the organic material has been mostly removed.) This deposition takes place through the activity of the bone cells which, as in cartilage, occupied the small minute spaces called **lacunae.** Note that the matrix is arranged in concentric layers called **lamellae.** These lamellae enclose circular openings called **Haversian canals,** which, in life, contain blood vessels and other structures.

On page 85, Fig. 37, sketch as accurately as possible a section of bone to show the above details.

(*d*) *Tissues. Muscular or contractile tissue.* 1. *Voluntary muscle.* Study the prepared slide of striated muscle furnished you. Note the long parallel muscle fibers or cells crossed by fine lines or **striations.**

88. Can you find any nuclei of the muscle fibers?

89. In what regions of your body would you expect to find muscle tissue of this type?

2. *Smooth muscle.* Study the circular muscle layer of the frog intestine. This is made up of smooth muscle or non-striated muscle.

90. What other name is given to this type of muscle? Why?

91. Can you see any nuclei of these muscle cells?

3. *Cardiac muscle.* Study the prepared slide of cardiac muscle furnished you. Compare this type of muscle with the two types already studied.

(*e*) *Tissues. Nervous tissue.* Under the demonstration microscopes, study the large motor cells, **neurons,** from the nerve cord of some vertebrate such as the pig, rabbit, or ox. Find the **axon** and the **dendrites** which originate from the cell body.

92. What are the functions of these parts of the neuron?

Aggregations of cell bodies form the gray matter in nervous tissue. Much of the white matter is composed of the cell processes. Study the nerve cord of the earthworm as seen under the demonstration microscopes. Note the large pear-shaped **nerve cells** in the ventral part of the cord. Note that the nerve cord appears to be double, that is, composed of two parts, and that the entire cord is enclosed in a sheath.

On page 85, Fig. 38, sketch several nerve cells.

THE PROCESS OF DIGESTION IN ANIMALS

(*a*) Put 10 cc. of thin starch paste in a test tube. Then add 1 or 2 drops of iodine solution.

93. What happens?

Now add at least 5 drops of saliva. Place in an incubator or water bath at body temperature (approximately 40° C.). Observe at intervals until the blue color disappears. Now test the solution in the tube with Benedict's solution.

94. How would you explain the change of color?

95. Recall the experiments on hydrolysis and catalysis (p. 8).

(*b*) Test a soda cracker for starch by adding iodine solution. Crush a cracker in water and test with Fehling's or Benedict's solution for sugar. Then chew up a cracker. After the mass is well mixed with saliva, put it in the test tube and test with Fehling's solution or Benedict's solution.

96. What is the result? Explain.

97. What is the source of the saliva?

98. What enzyme has brought about the change?

(*c*) Use five test tubes, marking them 1, 2, 3, 4, 5. In 1, place minced white of egg, 2 per cent hydrochloric acid, and pepsin. In 2, place minced white of egg and 2 per cent hydrochloric acid only. In tubes 3, 4, and 5, place minced white of egg, 2 per cent hydrochloric acid, and pepsin. Keep tubes 1, 2, and 3 in a warm place at a temperature about that of blood heat (37° C.). Immediately place 4 in an ice box or surround it with cracked ice, and keep it under these conditions until tested. Keep 5 in boiling water for 15 or 20 minutes, then put it in the warm place with 1, 2, and 3.

Test 1 with the biuret test. (To the material to be tested add one-half its volume of 10 per cent sodium hydroxide. Then mix and add a drop of 0.5 per cent copper sulphate solution. A violet or blue color shows the presence of unchanged protein; a rose-pink the presence of a peptone.) Test 2, 3, 4, and 5 also for the presence of a peptone.

99. Describe results.

100. What conditions are necessary for the digestion of protein?

101. In what organ are pepsin and hydrochloric acid formed?

(*d*) The enzyme **rennin** is secreted in the stomach. Dissolve a junket tablet, which contains rennin, in water warmed to 37°. Add a few drops of the rennin solution to a test tube half filled with milk warmed to approximately 37° and set aside where it will be undisturbed for one-half hour.

102. Describe your results.

(*e*) Add 10 cc. of artificial pancreatic juice (5 grains of ncreatin plus 10 grains of baking soda in 100 cc. of water) 1 cc. of dilute starch paste. Keep at body temperature a few hours; then test with Fehling's solution or Bene-t's solution.

103. Describe the results and explain.

(*f*) *Action of a lipase and steapsin, pancreatic enzymes.* each of two test tubes pour a few drops of pure olive oil. ld 5 cc. of 1 per cent sodium carbonate solution. Warm e two tubes and shake vigorously for a few seconds. Place e tubes in a rack, and allow to stand for a few minutes.

104. What is the result?

Now to each test tube add 5 cc. pancreatic solution. oil at once the contents of only one of the tubes. Then ake both tubes a few minutes and place them in an oven 40° C. for 6 minutes. Examine at intervals.

105. Does emulsification occur in either tube?

106. What other results do you observe?

107. What are your conclusions from the experiment?

These components of fats may be absorbed by the intestinal walls.

(*g*) Using 15 cc. of artificial pancreatic juice instead of a mixture of hydrochloric acid and pepsin, carry out an experiment as described for tube 3 of (*c*).

108. Was any white of egg digested?

109. What organ in the body secretes pancreatic juice?

110. What is the digestive action of pancreatic juice?

(*h*) Bile is secreted by the liver.

111. What is the function of the bile?

On page 87, Fig. 39, summarize your knowledge of the digestive glands and their secretions.

FOOD TRANSFER IN ANIMALS

NATURE OF BLOOD

(*a*) Examine the three bottles of blood on the supply ıble. This blood has been collected at a slaughter house. he blood in bottle 1 has been allowed to clot; in this bottle ou will note the solid part, the clot, and the yellowish quid part, the **serum.** The blood in bottle 2 has been efibrinated, and the **fibrin,** made up of threads, has been laced in bottle 3.

112. What is the function of fibrin?

(*b*) Examine a prepared slide of frogs' blood under high ower. Study the surface view of a red corpuscle. Note its hape and structure. If there is time, find a red corpuscle n profile view.

113. What is the shape of the red corpuscle of frogs' blood?

(*c*) Sterilize a finger by washing with alcohol. Then, ısing a needle or scalpel previously sterilized by heating, puncture the finger to procure a drop of blood. Make a thin smear of this blood on a slide in physiological salt solution and cover with a cover glass. Examine under the high power of the microscope. Study the red corpuscles in both surface and profile view.

114. Describe the red corpuscles of the human blood.

115. Do you find a nucleus?

116. How do these corpuscles differ from the red corpuscles of frogs' blood?

117. Why would you say that red corpuscles are cells?

Examine the slide carefully for clear colorless corpuscles, the **leucocytes** or white corpuscles.

118. What is the function of the white corpuscles?

On page 89, Fig. 40, draw a surface view of several human red blood corpuscles. Also draw one or two white corpuscles.

(*d*) Put a drop of blood on a slide, and add a few drops of physiological salt solution. Observe under the microscope. Now add a few drops of distilled water.

119. What happens to the red corpuscle?

This is known as **hemolysis.** Now place a drop of blood on the slide and add 2 per cent solution of sodium chloride.

120. What change do you note in the shape of the cells?

121. How would you explain this?

Now observe once more the drop of blood to which has been added the physiological salt solution.

122. Compare the reactions on both slides and explain.

(*e*) *Optional.* Examine a slide of human blood which has been stained with Wright's or Giesma's blood stains. Note the red corpuscles, but note particularly the **lymphocytes,** which have a very large nucleus and only a thin film of cytoplasm. Look for larger-sized white corpuscles whose nuclei are irregular in shape or are lobulated. These are **leucocytes.** Those whose cytoplasm contains purple- or lilac-colored granules are known as **neutrophils.** These leucocytes are highly phagocytic.

THE TRANSPORTATION SYSTEM

The heart. (Students work in pairs.) (*a*) Examine the demonstration specimens of the heart and lungs. (Use models of the heart and lungs of man or specimens taken from a pig or a calf.) The posterior and much larger portion of the heart is made up of the **right** and **left ventricles.** The muscular walls of the left ventricle are thicker than the walls of the right ventricle. Be sure to keep this in mind since it will assist you very much in your study.

At each side of the anterior end of the heart are the **auricular appendages,** parts of the **auricles.** Leading into the right auricle will be seen the roots of the **superior vena cava,** or **precava,** and the **inferior vena cava,** or **post cava,** which, respectively, bring the blood to the heart from the anterior and posterior parts of the body. Only the openings of these vessels may be seen. The one large vessel which

leaves the top of the right ventricle is the **pulmonary artery.** This carries blood to the lungs.

The blood is returned from the lungs by the **pulmonary veins.** Only the openings of these will be found in the left auricle. Below the left auricle is the muscular **left ventricle.** The blood leaves the left ventricle through the **aorta,** which will be seen as a large median vessel leaving the anterior end of the heart. A large branch of the aorta, the **innominate,** or **brachiocephalic,** soon divides into other smaller branches which carry blood to the head and anterior body regions. Near the innominate (or brachiocephalic), other branches of the aorta may be seen: the **left common carotid,** carrying blood to the head, and the **left subclavian,** supplying the left shoulder and arm. The aorta continues posteriorly and gives off branches that carry blood to the rest of the body. The relations of these vessels will be better understood when the internal structure of the heart is studied.

Complete the drawing on page 89, Fig. 41.

(*b*) Examine the internal structure of the heart (pig or calf).

123. Which have thicker walls, the auricles or the ventricles?

124. Why does the left ventricle have thicker walls than the right?

Note the opening between the right auricle and the right ventricle. Guarding this opening is the large **tricuspid valve,** which consists of three membranous flaps attached at the free ends to the wall of the ventricle by slender tendinous cords, the **chordae tendinae.** These, in turn, are attached to the walls of the ventricle. Leading from the upper corner of the ventricle is the tough white **pulmonary artery.** The opening through which the blood passes from the ventricle into this artery is guarded by three pouched, **semilunar valves.**

Leading to the left auricle are the **pulmonary veins.** Between the left auricle and the left ventricle will be found a large opening guarded by the **bicuspid** or **mitral valve,** which consists of two distinct flaps joined to the wall of the left ventricle by the **chordae tendinae.** Leading from the left ventricle is the **aorta.**

125. Do you find any valves in the aorta?

126. How does either the tricuspid or the mitral valve function?

127. What is the function of the chordae tendinae?

128. What is the function of the semilunar valves?

On page 91, Fig. 42, complete the semidiagrammatic drawing of the internal structure of the heart. Show by arrows the course of the blood through the heart.

THE CIRCULATORY SYSTEM OF A VERTEBRATE. THE FROG

(*a*) ***Arterial system of the frog.*** Use the frog already studied in a previous exercise. Be very careful to cut no blood vessels unless absolutely necessary. Most of the vessels can be seen by *gently* pulling the organs to one side.

The **conus arteriosus** originates near the base and on the right side of the ventricle. The heart may be somewhat distorted as a result of the process of injection. The conus passes into the **ventral aorta,** which continues obliquely across the two **auricles** and at the top of the heart divides into two branches. Each branch divides into three branches or **arterial arches:** the most anterior, the **carotid arch;** a middle one, the **systemic arch;** and the most posterior one, the **pulmocutaneous arch.** The carotid arch soon divides into a medial branch, the **external carotid artery,** and a lateral branch, the **internal carotid artery.** These carotid arteries supply most of the organs of the head. Where the carotid arch divides there is an oval swelling, the **carotid gland.**

The **pulmocutaneous arch** divides into a **pulmonary branch,** which goes to the lung, and the **cutaneous branch,** which supplies the skin, where blood is also oxygenated. Trace the course of this branch.

The **systemic arch** passes somewhat forward and laterally. Trace the course of the arch and note that it bends dorsally, passes around the esophagus, and joins the systemic branch from the other side. This union of the two systemic arches forms the **dorsal aorta.** Arising from the systemic arches are the **esophageal arteries** which supply the esophagus and the large **subclavian artery** which goes to the foreleg. The **laryngeal** and **occipito-vertebral arteries** are other branches of the systemic arches.

129. From the names of these arteries, can you suggest the regions supplied by them?

Where the two systemic arches join to form the aorta, a single large vessel arises, the **coeliaco-mesenteric artery.** This divides into the **coeliac artery** which supplies the liver, stomach, and pancreas, and an **anterior mesenteric artery** which supplies the intestines.

Trace the aorta posteriorly and note the small **urinogenital arteries** which pass to the kidneys and gonads. Posterior to these arteries the single median **posterior mesenteric artery** passes to the large intestine. The aorta then divides into the two **common iliac arteries.** Each **iliac artery** gives rise to a small **femoral artery** which passes to the muscles of the thigh. The iliac artery then continues down the leg as the **sciatic artery.**

In the outline of the frog on page 93, Fig. 43, locate and indicate the distribution of all the arteries mentioned. All the arteries mentioned can be readily found in well-injected specimens.

(*b*) ***The venous system of the frog.*** (*Optional.*) Those blood vessels which convey the blood toward the heart make up the **venous system.** A new injected frog may be necessary for this study. Open the abdomen of the frog as before, i.e., to the left of the median line of the abdomen. Be careful not to cut the rather prominent **ventral abdominal vein.**

ystemic veins. Remove the covering (**pericardium**) from heart. Then raise the tip of the heart, exposing the ıewhat triangular-shaped **sinus venosus.** This receives ·e large veins, the **posterior vena cava** or **postcaval vein,** .ch emerges from the liver and brings the blood from the terior body regions, and two **anterior venae cavae** or **caval veins,** which return blood from the head and empty ɔ the sides of the sinus venosus. Study the left precaval n and notice that soon after it leaves the sinus venosus livides into three branches, the most anterior of which he **external jugular vein,** which leads from the floor of buccal cavity. The middle branch of the precaval is **innominate vein,** the main branch of which is the **ernal jugular vein.** The most posterior branch of the ·caval vein is the **subclavian vein** which collects blood m the fore limb. The postcaval vein passes from the er to the sinus venosus. At its point of emergence from liver it receives two large **hepatic veins.** On tracing the stcaval further posteriorly, it is found to originate be- een the two kidneys from which it receives a number of **ıal veins.**

The hepatic portal system. A portal system is one which es not return the blood directly to the heart but carries to a certain organ from which it is later collected by some anch of the systemic system. The hepatic portal system llects blood from most of the internal organs, such as the ɔmach, pancreas, spleen, large and small intestines. This ood enters the liver through the large **hepatic portal vein,** large vein passing through the pancreas and dividing on e dorsal surface of the liver.

The renal portal system. The renal portal system leads to the kidneys. Study the kidneys and notice along the ıter border a conspicuous vein, the **renal portal vein.** On ıacing it back from the kidneys it will be seen to be formed y two veins which come from the leg, the outer of which is ıe **femoral vein** and the inner the **sciatic vein.** At the point here each femoral vein enters the body cavity, it receives branch, the **pelvic vein.** The two pelvic veins run along ıe posterior wall of the coelom and join in the median line ɔ form the **abdominal vein,** which passes on forward to join ıe hepatic portal vein previously described.

Carefully index the prepared drawing of the venous sys- em of the frog on page 95, Fig. 44.

(*c*) On page 97, Fig. 45, study the sketches of the arterial ystems of other animals and note the similarity of the rteries to those of the frog. Index the sketches as fully as ɔssible.

(*d*) *Circulation of the blood.* Study the circulation of the lood in the web of a frog's foot or the tail of a tadpole. If he animal is wrapped in a wet cloth and the membranes are ept moist, it will remain quiet, during the study. Using trips of cloth or adhesive tape, fasten one leg of the frog to thin board in which has been cut a hole one-half inch in diameter. Over this opening spread out the webbed foot and secure it by pinning the toes to the board. Now fasten the board to the stage of the microscope and observe under low power. Note the minute capillaries and the red corpuscles moving through them.

130. Describe any visible evidence of the influence of heart beat on the rate of blood flow.

(*e*) *Heart beat of the frog. Demonstration.* Pith a frog. (This operation is done as follows. Hold the frog with head upward in the left hand. Press the tip of the nose with the left index finger and bend at the junction of the head with the trunk. Push the point of the needle between the skull and the first vertebra and move the point of the needle from side to side in order to destroy the medulla of the brain. Push the point of the needle toward the nose, and destroy the brain by moving the needle from side to side. Remove the needle, and push it down the spinal cord, thus destroying this structure. The frog as an organism is now dead, but the organs will still exhibit their functions.) Now with the scissors carefully cut through the skin along the midline from the hind legs to the chin. Note the fluid, **lymph,** that fills the space between the skin and the body line. Now, using the scissors, make a small incision through the body wall and the pectoral girdle, exposing the heart. Observe the contraction of the ventricle.

131. How many times per minute does the ventricle contract?

132. Do the walls of the auricles contract?

133. Can you determine where the "heart beat" starts?

Add some warm physiological salt solution to the heart.

134. What changes take place in the beating of the heart?

Add some cold physiological salt solution to the heart.

135. What takes place?

Send a stream of cold water, warm water, or cold or warm salt solution onto the heart with a medicine dropper.

136. Does there seem to be any particular region that the stream must touch before the heart beat is affected?

(*f*) *Heart rate in man.* Find the pulse in the wrist as directed by the instructor. Count the pulse for one minute and report the rate. Make three counts, and take the average of the three. With the assistance of the instructor, record the pulse rates of all the individuals in the room. If it is a mixed group, keep the record of observations separate for the men and the women.

Now exercise for the interval as directed by the instructor, and proceed once more, as above, to record the pulse rate for all members of the class.

137. Summarize your data in a table.

Study your tabulated data. What do the data indicate as to:

138. The highest rate for men before exercising?

139. The highest rate for women before exercising?

140. The lowest rate for men before exercising?

141. The lowest rate for women before exercising?
142. The average rate for men before exercising?
143. The average rate for women before exercising?
144. The highest rate for men after exercising?
145. The highest rate for women after exercising?
146. The lowest rate for men after exercising?
147. The lowest rate for women after exercising?
148. The average rate for men after exercising?
149. The average rate for women after exercising?

150. What average increase in rate do you note for men after exercising?

151. What average increase in rate do you note for women after exercising?

(*g*) *Heart sounds. Demonstration experiment.* Under the direction of an instructor, use a stethoscope and listen to your own or fellow student's heart sounds.

152. Describe the sounds.

153. What is the instructor's explanation for the sounds?

RESPIRATION

INTRODUCTION

The products of burning. (*Instructor's experiment. To be written up outside of class.*) Place a small lighted candle in a bottle and, after the flame disappears, insert a flaming splint.

154. What is the result? Explain.

Pour into the bottle 10 cc. of limewater or barium hydroxide, and shake.

155. What is the result? Explain.

Hold a cold bottle over a flame.

156. What do you observe?

Breathe upon a cold piece of metal or glass.

157. What takes place?

Breathe through a glass tube into a test tube one-fourth full of limewater or barium hydroxide.

158. What takes place?

159. What conclusion do you draw from the above observations regarding the process of respiration? Explain fully.

RESPIRATION IN PLANTS

(*a*) Place ten peas in a stender dish, on moist cotton or filter paper. Place this dish and a small open vessel containing limewater or barium hydroxide in a germinating chamber closely sealed with vaseline. Observe after several days.

160. What change takes place in the limewater or barium hydroxide? Why?

161. Does respiration take place in a germinating seed?

162. What proof of your statement can you offer?

Place a small coleus or geranium plant and an open vessel of limewater or barium hydroxide under a bell jar. Seal the bell jar to a glass plate with vaseline. Allow to stand overnight.

163. Do you note any change in the appearance of the limewater or barium hydroxide? Explain.

164. Recall the structure of the leaf and explain how oxygen-carbon dioxide exchange takes place in higher plants.

(*b*) Fill a thermos bottle two-thirds full of germinating seeds (previously soak seeds in water, not more than 16 hours). In another thermos bottle place an equal quantity of similar seeds that have been killed by immersing them in boiling water for 5 minutes and then cooling thoroughly. Sterilize both lots of seeds with 3 per cent formalin. Place a thermometer in each thermos bottle so that its bulb rests at about the center of the mass of seeds, and support it in position by a cotton plug. Record the temperature reading periodically for several days. (Time periods suggested by instructor.)

165. What conclusions concerning respiration may be drawn from this experiment?

(*c*) (*Optional.*) Place approximately 5 cc. of germinating seeds in a test tube and hold them in place by inserting a small wad of absorbent cotton. Now invert the test tube in a shallow dish containing potassium hydroxide. (Potassium hydroxide absorbs carbon dioxide.) Set up another test tube in the same way, substituting water for the potassium hydroxide. Observe at the end of 24 hours.

166. What has happened?

167. How do you account for this?

(*d*) (*Optional.*) Place some moist cotton and soaked seeds upon the top of a wire frame in a large beaker. Pour some potassium pyrogallate into a dish. (Potassium pyrogallate absorbs oxygen.) Now invert a small beaker over the wire frame and place a cover over the larger beaker. Run a control using water in place of the potassium pyrogallate.

168. Record and explain results.

(*e*) *Fermentation. Anaerobic respiration.* (*Individual or instructor's experiment.*) Carefully fill a fermentation tube with a mixture of molasses and water, and add a little piece of compressed yeast cake. Plug the open end with absorbent cotton. Set in a warm place overnight. Observe the next day.

169. What has happened in the filled end of the fermentation tube?

170. How do you account for this?

(*f*) (*Individual or instructor's experiment.*) Partly fill an Ehrlenmeyer flask with a mixture of molasses, water, and compressed yeast cake. Close the flask with a stopper fitted with a delivery tube which leads into a corked test tube filled with limewater or barium hydroxide. Observe after a day or two.

171. What has happened to the limewater or barium
lroxide?
mell the contents of the flask.
172. What causes this odor?
173. What happens when fermentation takes place?
plain fully.

RESPIRATION OF ANIMALS

(*a*) *Breathing movements of the frog.* Place a live frog in
overed glass dish and, after it has become quiet, study
manner of breathing. Three regions should receive
cial attention, the nostrils or **external nares,** the floor
the buccal cavity, and the sides of the trunk.
174. After careful study describe how the frog takes air
o its lungs (inspiration) and expels air (expiration).
175. How does the breathing of the frog differ from that
man?
(*Demonstration by instructor.*) Kill a frog by pithing or
the use of ether. Expose the viscera by dissecting as
eviously directed. Insert a glass tube or blow pipe in the
ttis and force air into the **lungs.**
176. Why is it necessary for the walls of the lungs to be
astic?

(*b*) At their anterior ends the two lungs open into a cham-
r, the **larynx.** This connects with the pharynx through a
t-like glottis. The larynx lies just in front of the heart.
emove all the muscles from the under surface of the lower
w and expose the flat, smooth, somewhat shiny **hyoid**
rtilage. From the hyoid cartilage the two **thyroid proc-**
sses extend posteriorly around the laryngeal chamber.
ow find the connection of the **lungs** with the larynx.
ext slit open the ventral wall of the larynx and look for
e **vocal cords,** a pair of longitudinal folds. Note where
e lungs open into the walls of the larynx. Open the wall
the lung, beginning at the larynx and extending the cut
osteriorly. Note that the inner wall of the lung is raised
p into a network of ridges forming between them a num-
er of small chamber-like depressions called **alveoli.** Blood
essels are found in these ridges, and these supply the
alls of the alveoli.
Complete and index fully the drawing on page 99, Fig. 46.
177. What artery supplies blood to the lung?
178. What blood vessels besides arteries are present in
he lungs?

(*c*) *Rate of breathing.* Count the normal rate of breath-
ng of your partner by observing the breathing of your part-
ner in a sitting position. Make three counts of a minute
ach and then average the results. Now, with the assistance
f the instructor, compile the average breathing rates of all
he students in the class. If it is a mixed group, keep the
ecord of observations separate for the men and for the
women.
Now exercise as directed by the instructor for a brief
period, and record the results as above.

179. Summarize your data in a table (use the method practiced for the experiment on page 13).
180. Study your tabulated data. What do the data indicate? (Recall interpretations asked for in experiment on page 13.)

(*d*) *Mechanics of breathing.* Place your hands upon the lower ribs and note the movement of the ribs during inspiration and expiration.
181. Describe the movement of the ribs.

(*e*) *Measurement of air expelled in breathing.* (*Optional demonstration experiment.*) The volume of air expired may be determined by means of the expirometer. The expirometer measurements may be made either in cubic centimeters or in cubic inches. Breathe normally through the tube and measure the amount of air expired. The average amount for the adult man is 500 cc. This is known as **tidal air.**
182. What is the amount of air expelled?
183. Suppose that the rate of breathing remains the same at all times. What would be the total volume of air used during the 24-hour period?
Now determine the **vital capacity** of your lungs. This is done by measuring the quantity of air that can be breathed out by the deepest possible expiration after making the deepest possible inspiration. The average figure for the adult man is 3700 cc.
184. Compare the vital capacity of your lungs with others in the class.
185. With the assistance of the instructor, determine the average amount per student for the class.
186. If you are in a "mixed" class, how does the amount of air expired compare between the sexes?
187. How does the process of breathing of a man differ from that of a frog?

(*f*) *Mechanism for the elimination of foreign particles from the lungs.* (*Demonstration experiment.*) The trachea of mammals is lined with a ciliated epithelium. The waving of these cilia carry the mucus-trapped particles up the trachea. This action may be illustrated by the following experiment, in which, however, the direction of movement is the opposite of that found in the trachea. From a pithed frog remove all of the organs except the esophagus and stomach. Pin the head in a dissecting pan, ventral side up. With the scissors cut through the pectoral girdle in the mid-ventral line. Cut across the lower jaw on a line between the angles of the jaw. Now, with the scissors, slit the stomach and the esophagus and pin out the walls laterally. Be sure to keep the surface of this preparation constantly moistened with physiological salt solution. Now place a small piece of cork on the exposed surface of the esophagus.
188. In which direction is the piece of cork propelled?
189. What is the rate of movement?
Tilt the preparation in the dissecting pan, and determine if the cork can be moved uphill.

Return the preparation to the original position, add a drop of cold physiological salt solution (approximately 20° C.), and repeat.

190. What difference do you note?

(*g*) Repeat the experiment with warm physiological salt solution (37–40° C.). Flood the preparation for five minutes with this warm solution. Remove the excess solution and repeat the observation made under normal conditions.

191. What change do you note?

EXCRETION

EXCRETION IN PLANTS

(*a*) Pour 5 cc. of the indicator solution (bromthymol blue or any other suitable indicator) into a test tube and add a few drops of acid.

192. What change takes place?

Now fill a bottle with the indicator solution and in this place a growing seedling. Observe it the next day.

193. What change has taken place?

194. What does this prove?

195. What would be the reason for adding lime to the soil?

(*b*) Cut a thin cross section of a twig of apple or basswood, or the petiole of an oak leaf, and mount the section in water on a slide. Observe with the microscope and try to locate some of the large aggregate crystals of calcium oxalate.

(*c*) Cut thin cross sections of a geranium stem, mount in water on a slide, and examine them under the microscope for epidermal hairs. Among these are many with enlarged ends composed of glandular cells.

(*d*) (*Demonstration.*) Select a potted plant and enclose both pot and soil in a water-proof covering, leaving only the stem and leaves exposed to air. Place the plant under a bell jar and seal the jar to a glass plate with vaseline. Run control experiments by placing a vessel of water under a second bell jar and nothing under a third one. Observe periodically.

196. What does this experiment show?

(*e*) (*Demonstration.*) Remove a small branch from some shrub such as privet. Under water, cut off 10 cm. of the basal end of the branch. This must be done to prevent the entrance of air into the vessels. Attach a piece of rubber tubing to the lower end of a graduated burette and fill both tubing and burette with water. Under water, insert the cut branch into the free end of the tubing. Twist copper wire about the tubing to secure a tight union between the branch and the tube. Using a ringstand and clamps, fasten both the branch and the burette securely in an upright position and make periodic readings for several days.

197. Determine the average rate of water loss per hour.

(*f*) (*Demonstration.*) Suspend a leaf of rubber plant (or any xerophyte) and a leaf of *Begonia* (or any mesophyte) where they are freely exposed to the air. Make thin sections of other samples of these leaves and carefully note any differences in structure. Make daily observations for a week.

198. Record and explain results.

EXCRETION IN ANIMALS

(*a*) *Urinogenital system of the frog.* Cut through the small intestine of the frog where it joins the rectum. Now carefully free the alimentary tract from the mesenteries and lay it to one side. Observe the flattened, dark-colored bodies, the **kidneys,** which lie close to the dorsal body wall. In front of these may be found yellow, finger-like **fat bodies.** The urinary system and the reproductive system are so closely related anatomically that they can be studied most advantageously by introducing both in this place.

If the animal is a female, the kidneys will be hidden by a mass of eggs which are enclosed in the **ovaries.** The large convoluted white tubes are the **oviducts.** Completely remove the eggs and oviducts from one side. Notice that just before the oviducts enter the **cloaca,** they enlarge and the walls become more loose and "flabby." This portion of the tube is the **uterus.** If the animal is a male, two yellow, oval **testes** will be found connected to the kidneys by mesenteries.

Now with a scalpel carefully cut through the muscles and bones and expose the continuation of the alimentary tract and the **cloaca.** Each kidney is connected with the cloaca by a tube, the **ureter,** which in the female carries urine only. In the male this tube conveys both urine and male gametes or **spermatozoa** to the cloaca. This tube is known as the **Wolffian duct.** In the higher animals the tube draining the kidneys is called the **ureter.**

In the male, a thin convoluted tube is often present extending along the external lateral border of the kidney. Do not mistake this for the Wolffian duct. This is the **rudimentary oviduct.** The rudimentary oviduct joins the Wolffian duct and at the point of union there is an enlargement, the **seminal vesicle.** On the ventral wall of the cloaca, and near the place where the Wolffian ducts open into the cloaca, will be found a bilobed sac, the **urinary bladder.** On the ventral median surface of each kidney will be found a line of spots or dots which vary in color from light to dark brown. These are the **adrenal bodies,** which are endocrine or ductless glands.

On page 101, Fig. 47, complete the drawings of the urinogenital system showing the above-mentioned parts.

(*b*) Compare the urinogenital system of the frog with that of the cat (furnished by the instructor) and index the prepared drawing on page 103, Fig. 48.

Carefully label the frog and keep it for further study.

IRRITABILITY

TROPISMS

(*a*) (*Demonstration.*) Germinate a number of radish eds in a shallow dish. When the leaves begin to appear, ace the dish in a phototropic chamber. After 24 to 48 urs examine the plants and note the position of the stem d leaves with reference to the source of light.

199. Has there been any change in position? If so, how you account for it?

200. (*b*) (*Demonstration.*) Note the position of the aves on some plant such as *Oxalis* at different times during e day.

201. Is there any change in the position of the leaflets?

202. Are there any other plants, especially leguminous ants, that show similar changes?

203. What name is given to such responses?

(*c*) (*Demonstration.*) Arrange a seedling, growing in a ower pot, over a tripod with the shoot downwards; place n the dark for 36 hours.

204. What position is assumed by both root and shoot?

205. How do you account for this?

206. What is such a response called?

(*d*) (*Demonstration.*) Place a potted seedling with an pright stem in a clinostat which revolves slowly and bring o a horizontal position. Observe after 24 hours and record ny differences in the direction of growth.

207. Explain your results.

(*e*) (*Demonstration.*) Germinate a number of beans, peas, r radish and corn seeds in a germinating box. When the econdary roots have begun to develop, notice the general direction of growth. After they have reached a length of a ew centimeters, tip the box so that the top makes an angle f 45 or 50 degrees. With chalk or "china" marking pencil, nark the position of the roots on the glass side, and make daily observations to determine if the lateral roots change heir position.

208. Write in detail your observations and explain your results.

(*f*) Germinate some peas or beans. When the roots are 15 mm. long mark them off into 2-mm. spaces with India ink. Place some of the seedlings in a moist chamber in a horizontal position by pinning them to large corks. At the end of 24 hours or more determine what part of the root has made the curvature.

209. What do you understand by irritability?

210. How is the response of plants brought about?

211. Would you say that a plant is conscious?

212. Of what importance in the life of the plant is this response?

(*g*) (*Demonstration.*) Place a number of daphnids in some water in a glass jar. Darken one part of the jar and focus the light on another part.

213. Describe the response of the animals.

Repeat the experiment by reversing the light and dark regions.

214. What name would you give to this response?

(*h*) *Reactions to light.* Place ten or more fruit flies in a glass tube; a test tube will be satisfactory. Now cover three-fourths of the length of the tube with dark paper or dark cloth to exclude the light. Move all the flies into the dark end of the tube by tapping the glass. Lay the tube horizontally on the table.

215. At which end of the tube do the flies congregate?

216. What type of tropistic reaction does this behavior illustrate?

(*i*) Fill one end of a dissecting pan with dry sand and the other end with moist sand. Place three or four live earthworms in the dissecting pan. Cover with another dissecting pan to exclude the light. Observe at half-hour intervals, and each time record the number of worms on the dry sand and the number on the wet sand.

217. Averaging the results of all observations made, at which end of the pan do you find the larger number of worms?

(*j*) (*Demonstration.*) Examine the leaves of a sensitive plant (*Mimosa pudica*). Note the swellings or pulvini at the lower ends of the petioles. Touch one of the leaves lightly.

218. Describe what happens.

219. Is this response brought about by muscular action or in some other way? Explain.

REFLEXES

(*a*) *Knee jerk.* Sit on a table or desk, and allow the leg to hang free from the knee. Have your partner strike the patellar ligament just below the knee-cap with the edge of a ruler or some other instrument furnished by the instructor.

220. What is the result?

Before striking the ligament, allow the subject to clench his fist and have him add a column of figures. Now tap the ligament.

221. What is the result?

(*b*) *Ankle jerk.* Let the subject kneel on a chair with the feet hanging over the edge of the chair. With a ruler, tap him on the tendon of Achilles. (Ask instructor for location of this structure.)

222. Note the results.

These reflexes are called **tendon reflexes,** because the stimulation is applied to a tendon or ligament.

(*c*) *Swallowing reflex.* Allow a small amount of water to come in contact with the pharynx or the posterior part of the tongue.

223. What happens when the water touches the pharynx?

224. Can you prevent this reaction?

(*d*) *Eye reflex.* Close the eyes for a few minutes, then face a bright light. Open them, and allow your partner to examine them immediately. Repeat this experiment with your partner.

225. Record results.

SPECIAL RECEPTORS OF A VERTEBRATE ANIMAL

(*a*) *Smell.* Note the pair of irregular openings in front of the mouth of the dogfish. These are the nostrils. Probe the nostrils. Now study the nostrils of the frog.

Carefully dissect the skin away from around the nostrils of the dogfish. Within is a soft oval body, the **nasal capsule.** Dissect this from the body. Note the large size of the capsule and its connection with the **olfactory bulb** of the brain. Open the capsule by cutting parallel to its long axis and note the **folds** in its mucous membrane.

226. What is the function of these folds?

227. How do the nostrils of the dogfish differ from those of the frog? Why?

Examine the longitudinal section through a mammalian skull such as the skull of a cat or a dog.

228. How do these nasal passages differ from those of the dogfish and frog?

229. Which animal does the plan of your nasal passage resemble?

(*b*) *Taste.* Dry the surface of the tip of the tongue. Place a crystal of sugar upon the tip of the tongue.

230. Do you taste the sugar?

Now repeat with a crystal of salt.

231. Do you taste the salt?

Now moisten the tip of the tongue with saliva and repeat the experiment.

232. How do you explain the results?

(*c*) *Sight. The compound eye of Arthropoda.* Study the external appearance of the compound eye of an insect or a crayfish with the low power of the microscope. Note that the outer surface of the eye is covered with a tough transparent coat, the **cornea.** The cornea is marked off into a number of small divisions called **facets.** Each facet is the outer end of a **simple eye** called an **ommatidium.**

On page 105, Fig. 49, sketch four or five adjacent facets of a compound eye.

(*d*) *The vertebrate eye.* Cut away the eyelids of the right eye of the dogfish and the cartilaginous ridge of the skull which surrounds it so as to expose the **orbit,** the cavity in which the **eyeball** lies. Study the eyeball. The central area or **pupil** (which appears white in the preserved specimen), through which light is admitted to the eye, will be seen surrounded by the black **iris.** Covering the entire eyeball is a tough outer coat, the **sclera,** which becomes transparent over the iris and pupil. It is this transparent area that is called the **cornea.** Covering the front of the eyeball is a thin transparent membrane, the **conjunctiva.**

On page 105, Fig. 50, sketch the frontal aspect of the eyeball (X2).

(*e*) *Muscles of the eye.* There are six muscles which move the eye. Remove the mucous-like material from around the eye and from the orbit. Now press the eyeball downward. Note the two muscles which are attached near the median region. The anterior muscle is the **superior oblique** and it is attached within the orbit to the anterior wall. The posterior one is the **superior rectus muscle** and it is attached to the posterior wall of the orbit.

233. What would be the action of each of these muscles on the eyeball?

Press the eyeball upward and note the **inferior oblique muscle** on the ventral side of the eyeball. It goes to the anterior wall of the orbit. The **external rectus muscle** is seen on the posterior ventral wall. Cut the muscles observed thus far as *close to the wall of the orbit as possible.* Note the **inferior rectus muscle** which is attached to the lower side of the eyeball. A fourth rectus muscle, the **internal rectus,** is the most anterior of the rectus group. Note its insertion on the eyeball.

234. What would be the action of each of the above-named muscles on the eyeball?

Cut the inferior rectus muscle close to the wall of the orbit. Find the **optic nerve** and cut it midway between the wall of the orbit and the eye. Remove the eyeball from the orbit.

On page 105, Fig. 51, sketch (X2) the back of the eyeball, showing these muscles and the optic nerve.

(*f*) *The internal structure of the eyeball.* Cut the eyeball into two parts by making an incision through the pupil. Continue the incision completely around the eyeball, separating it into halves. Place these in a glass dish filled with water. The wall of the eyeball will be found to be made up of three main coats, an outer tough white **sclera** which becomes transparent over the **iris** and **pupil** to form the **cornea**; a dark middle coat known as the **choroid**; and a rather soft gray inner coat, the **retina,** which in the dissection may have been loosened from the other two. The retina will be found to be an expansion of the **optic nerve.** Note where the optic nerve enters the eye and passes through the sclera and choroid coats. The spherical **crystalline lens** lies near the front of the eye. The cavity of the eyeball is thus divided into two regions. One region lies between the lens and the cornea and iris, and is filled with the watery **aqueous humor.** The cavity between the lens and the retina is occupied by the **vitreous body.**

Complete and index fully the prepared drawing of the ion of the eye on page 107, Fig. 52.

g) *Ocular Refraction.* (*Demonstration experiment.*) There many types of eye models on the market by which many eresting points of refraction, accommodation, and errors refraction can be demonstrated. These models differ y largely in their construction, so no specific directions n be given. The student should verify by means of the rticular model available the following:

1. The image on the retina is a real and inverted image.
2. Far and near objects do not have their foci upon the ina at the same time.
3. When the eye is adjusted for the far object, the near ject has its focus back of the retina.
4. To bring the focus of the near object upon the retina, e refractive power of the lens must be increased.
5. The refractive power of a lens varies inversely as its dius of curvature.
6. With a large aperture (pupil) the image is rendered less stinct (spherical aberration). This defect is lessened by nstriction of the pupil and is caused by the peripheral ys coming to a focus sooner than the central rays.
7. The eye can be made myopic by increasing the distance tween the refracting surface (cornea) and the retina. rove that in this case the nearest point (or "near point"), hich by accommodation can be focused upon the retina, s nearer than in the emmetropic eye.

(*h*) *The ear.* (*Optional.*) In fishes there is only an inter- al ear. There are no auricular appendages or ear openings ich as are found in higher animals. This primitive type of ar in the dogfish consists of a membranous labyrinth of ree **semicircular canals** and a **vestibule** located in a car- laginous capsule just posterior to the orbit on each side. or the study of this internal ear, very careful and patient issecting is required.

First remove all skin and muscles from the top of the head ack of the orbit from which the eye was dissected. In the oof of the skull a raised elevation or slight ridge will be seen xtending backward from the orbit; in and just beneath this ill be found the **anterior vertical semicircular canal.** have off the cartilage in very thin flat flakes. Soon there ill appear a rather clear area, a hollow cavity in the artilage, in which the delicate tubular canal will be found. Extending posteriorly from the junction of the anterior ertical canal with the vestibule is the **posterior vertical emicircular canal.** Arising from approximately the same orsal level as the posterior vertical canal and reaching to he ventral end of the anterior vertical canal is the **hori- ontal semicircular canal.** Note the **ampullas,** the swollen nds of the canals where they join the **vestibule,** a delicate accular structure more deeply embedded in the cartilage. eading from the dorsal surface of the vestibule to the outer kin is a small tube, the **endolymphatic duct.**

235. Are there ampullas on both ends of each canal?

236. Explain how the internal ear functions.

237. How does a fish "hear"?

Make a drawing of your dissection if you so desire.

(*i*) *Equilibrium.* Place a frog on a board and slowly turn the board in a circle.

238. While this is being done note the position of the frog's body, head, and legs.

239. Again observe the action of the frog when the rotation is stopped.

240. What structures are concerned in maintaining posture?

(*j*) *Cutaneous sensation.* Observe the demonstration slide of a tactile corpuscle under the demonstration microscope.

241. Describe the structure.

Now touch the skin of the hand or forearm with the pointed end of the needle. Use gentle pressure. Note those spots which give pain and the spots which give sensation of being touched.

Now touch the skin with a point of a nail which has been cooled in ice water.

242. Can you feel the cold point of the nail at every place touched?

Repeat the experiment using another nail which has been in hot water.

Outline an area of one inch square on your forearm. On page 107, Fig. 53, outline this same area. Now, following the procedure outlined above, proceed to map the location of the pain spots, touch spots, and cold spots. Use colored spots of ink or pencil to designate the distribution of the different spots.

243. Which of the four sensory endings are most numerous?

244. Which type is most easily stimulated?

245. Is there any region where more than one sensation can be perceived?

THE BRAIN AND CRANIAL NERVES OF A VERTEBRATE ANIMAL

(*a*) *The brain. Dogfish.* Remove the skin and muscles from the dorsal surface of the head, thus exposing the cartilaginous skull. The small hole seen in the top of the head was made to permit the preserving fluid to get into the cranial cavity. Through this opening the brain can be seen. After the brain has been thus located, carefully dissect away the roof of the skull, being careful not to cut any nerves or the structures in the orbits.

The brain, as seen in dorsal view, is made up of five regions. The foremost region is the **telencephalon.** The most anterior parts of this region are the **olfactory bulbs,** masses of nervous tissue in contact with the **nasal sacs.** The olfactory bulbs are connected to the main part of the telencephalon by the **olfactory tracts.** Note the two some-

what rounded **cerebral hemispheres.** The **diencephalon,** from which the optic nerves arise, is the next division. The third region is the **midbrain** or **mesencephalon,** on which are located a pair of rounded swellings, the **optic lobes.** Then follows the **cerebellum** or **metencephalon,** an elongated medial oval structure partially covering the optic lobes and extending posteriorly over the last division, the **medulla oblongata** or **myelencephalon.** The **medulla oblongata** leads imperceptibly into the **spinal cord.** Its delicate dorsal wall is often removed in the dissection, exposing a large depression, the **fourth ventricle.** The anterior lateral regions of the medulla form a pair of projections lying lateral to, and underneath, the cerebellum, called the **restiform bodies.**

On page 109, Fig. 54, complete the drawing of the dorsal view of the brain. Index all the parts.

(*b*) *The cranial nerves.* (*Optional.*) In the dogfish there are ten cranial nerves arranged in pairs. The **olfactory nerve** (I) is the first cranial nerve. This is not a single nerve but a group of minute fibers which pass from the olfactory bulb into the nasal capsules.

The **optic nerve** (II) arises in the diencephalon and passes to the eye through a foramen or hole in the skull. Find this nerve.

The **oculomotor nerve** (III) supplies certain muscles of the eye. It is a small nerve which emerges from the ventral surface of the optic lobe (mesencephalon) and enters the orbit just back of the optic nerve. Identify this nerve.

The **trochlear** or **pathetic nerve** (IV) is a delicate nerve which will be found on the side of the brain between the cerebellum (metencephalon) and the optic lobe. Unless the dissection has been carefully done, this nerve may be missing.

The **trigeminal nerve** (V) emerges from the side of the anterior end of the medulla (myelencephalon) near the posterior end of the cerebellum. Closely surrounding this nerve at its origin are the roots of the **facial** (VII) and **auditory** (VIII) **nerves.** Carefully chip away the skull and expose these three nerves.

(*Optional.*) Near the point of emergence of the trigeminal nerve two branches are given off, the **superficial ophthalmic** and the **deep ophthalmic,** which pass forward to the snout. Two other branches of the trigeminal, the **maxillary** and the **mandibular,** enter the orbit as one trunk and form a broad band of fibers which divide into the anterior **maxillary branch** and the posterior **mandibular branch.**

The **abducens nerve** (VI) is a small nerve which will be seen later on the ventral surface of the brain when it is removed.

The **facial nerve** (VII), already identified with V and VIII, also divides into three branches.

(*Optional.*) The **superficial opthalmic branch** follows the path of the superficial **opthalmic** of the trigeminal (V). The **hyomandibular branch** may be located back of the spiracle. Trace it inward to the brain. The **palatine branch** will be found passing from the region of the hyomandibular trunk close to the brain.

The **auditory nerve** (VIII) is a short nerve already identified. It enters the auditory capsule almost immediately.

The **glossopharyngeal nerve** (IX) emerges from the myelencephalon some distance back of the auditory nerve. Press the wall of the skull away from the brain and identify this nerve.

The **vagus** or **pneumogastric nerve** (X) arises from the lateral dorsal surface of the myelencephalon by a number of roots. Besides supplying many of the gill arches, its main branch supplies the heart, stomach, and other organs.

Carefully complete the prepared outline of the brain and cranial nerves on page 109, Fig. 55. Index the regions of the brain and the cranial nerves. Use crayons and color the various regions of the brain.

(*c*) *The ventral surface of the brain.* Carefully chip away the remaining portion of the skull. Cut the cranial nerves, leaving as much of the nerve attached to the brain as possible. Expose the entire dorsal surface of the brain and part of the spinal cord. Loosen the olfactory bulbs and bend the telencephalon back so that the ventral surface of the brain may be seen. Identify the small **abducens nerves** (VI) and cut them. Notice the **optic nerves** (II) and back of them some structures embedded in the floor of the skull. Carefully dissect the brain from the skull, keeping these structures intact. After the brain is removed notice that the two optic nerves apparently meet in the median region to form the **optic chiasma.** They continue into the brain as the **optic tracts.** Back of the optic chiasma will be seen the rounded **pituitary body.**

246. What is the function of the pituitary body in the higher vertebrates?

247. How can you identify the various regions of the brain from its ventral aspect?

On page 111, Fig. 56, complete the sketch of the ventral view of the brain and its structures. Use crayons and color the various regions of the brain previously mentioned.

(*d*) *The brain of the frog.* (*Optional.*) Remove the skin and muscles from the dorsal region of the head of the frog and expose the bones of the skull. With the point of the scalpel carefully strip off the thin bones of the roof of the skull to expose the brain. Carefully remove all the bones of the skull as well as the dorsal parts of the vertebrae. With the anatomy of the dogfish brain in mind, identify the following regions of the brain: **olfactory lobes, cerebral hemispheres (telencephalon), diencephalon, optic lobes (mesencephalon),** the narrow band of the **cerebellum (metencephalon),** and the **medulla oblongata (myelencephalon).**

248. Compare the brain of the dogfish with the brain of the frog.

he myelencephalon merges into the spinal cord, which inates posteriorly in a fine thread, the **filum terminale.** emove the brain and spinal cord from the frog, taking ial care not to lose the **pituitary body.** Keeping in mind anatomy of the dogfish brain, identify: the **optic nerves, c chiasma, optic tracts,** and **pituitary body.**

49. Compare the ventral aspect of the frog's brain with t of the dogfish.

Carefully complete and index the prepared drawing of the in of the frog on page 113, Fig. 57. Make additional wings of the brain if you so desire.

VERTEBRATE LIMBS

t is a familiar fact that the bodies of all backboned mals contain bones. This is so well known that it is

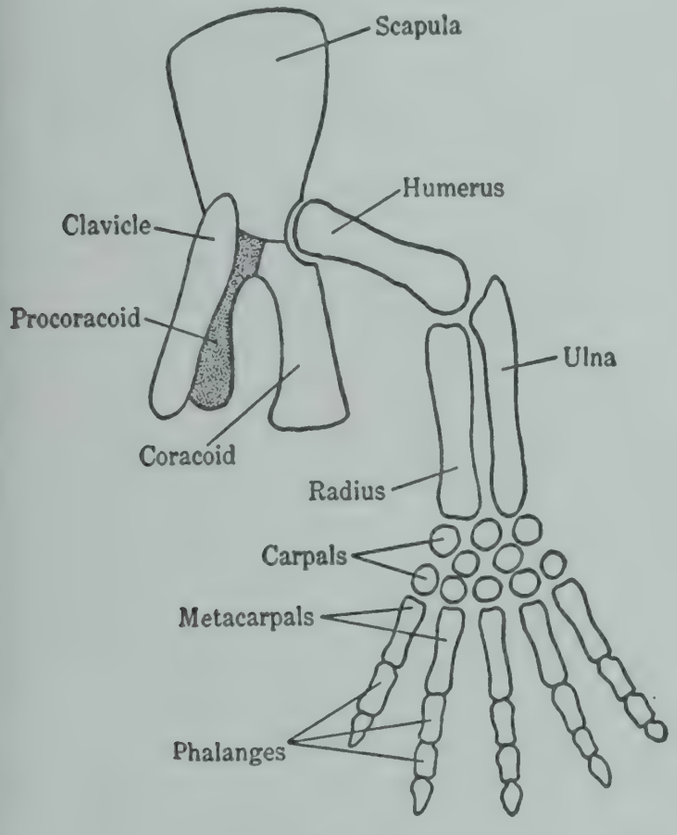


Fig. A.

oubtful if many people give much thought to the real purose of bones. While the skeleton serves various functions, uch as giving shape to the animal and providing protection or it, the most important general function is that it is an ntegral cog in the effecting mechanism.

The bones are articulated into a skeletal system of levers nade workable by a system of joints. These levers have nuscles attached to them at strategic points, and the contraction of these muscles is responsible for the movement of he animal as a whole or for any part of it. Thus it may e seen that this musculo-skeletal system is the effecting nechanism, the tool and machine of the directing nervous ystem.

The following general description of the vertebrate skeleton holds true for practically all the animals of this group. If we study the foreleg and foot of the frog, the arm and hand of man, and the wing of a bat, they are all seen to have a structural likeness, and it will be seen later that they have a similar origin as well. Such structures are said to be **homologous.**

Before attempting the study of adult vertebrate limbs it will prove advantageous to know what divisions or structures may be present in a typical generalized hypothetical limb. In this study we shall begin with a typical hypothetical pentadactyl (5 fingers) limb. Consult and study the diagram, Fig. A.

(*a*) *Pectoral girdle and the fore limb.* The **pectoral girdle** is made up of the shoulder blade, the flattened **scapula,** together with the **clavicle** or collarbone and the **coracoid.**

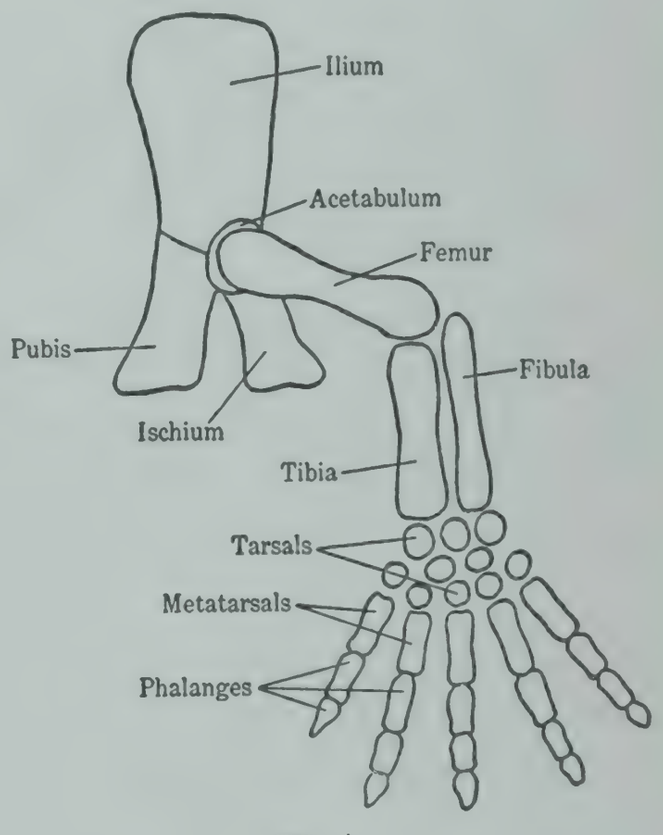


Fig. A.

(The **procoracoid** is in close contact with, or often invested by, the clavicle.) Attached to the pectoral girdle is the fore limb, made up of the **humerus** or upper arm, which fits into the **glenoid cavity** of the scapula; the forearm, made up of the **radius** and **ulna;** the wrist of ten (or fewer) small irregularly shaped **carpal bones.** Following these are the five **metacarpals** and the fingers composed of small bones, the **phalanges** (singular, **phalanx**). Study the diagram, Fig. A.

(*b*) *The pelvic girdle and the hind limb.* The **pelvic girdle** is composed of the following bones: the **ilium, ischium,** and **pubis,** all closely fused together. The thigh bone, or **femur,** articulates with the pelvic girdle in a cavity called the

acetabulum. Attached to the femur is the lower leg made up of the **tibia** and **fibula.** At the lower end of these may be ten (or fewer) **tarsals** or ankle bones, followed by the five **metatarsals** and the five toes made up of **phalanges.**

(*c*) *The pectoral girdle and fore limb of the frog.* The **pectoral girdle** is the bony structure with which the fore limb articulates. It consists of a rather broad bone, the **scapula,** located lateral to the backbone. Attached to the dorsal side or top of the scapula is the **supra-scapula,** a rather broad bone extending over the back. In the ventral end of the scapula is the shallow **glenoid cavity,** in which fits one end of the upper bone of the arm, the **humerus.** Extending from the ventral end of the scapula and toward the very primitive **sternum,** or breastbone, are two well-defined bones; the anterior one is the **clavicle** and the posterior one is the **coracoid.** These bones appear to meet and fuse with the clavicle and coracoid from the other side of the animal. A projection extends anteriorly from the girdle beyond the clavicles and is made up of a terminal cartilage, the **episternum,** posterior to which is the bony **omosternum.** Another process, extending posteriorly beyond the coracoids, is made up of the terminal cartilaginous **xiphisternum** and the bony sternum proper. Note the **humerus** in the upper arm and the **radio-ulna** in the forearm.

250. Which of the fused bones is the radius?

The wrist is made up of a number of fused **carpal bones.** In the hand are the **metacarpals** and **phalanges.** Compare the bones of the girdle and arm with those of the typical pentadactyl girdle and arm.

On page 115, Fig. 58, complete and index the prepared drawing of the pectoral girdle and fore limb of the frog.

(*d*) *The pectoral girdle and arm of man.* With the anatomy of the frog in mind, and with the aid of the diagram, study the pectoral girdle and forearm of man. Identify the **scapula, clavicle** (collarbone), **coracoid process** (which is the rudiment of the **coracoid bone,** fused to the scapula), the **humerus, radius, ulna, carpals, metacarpals,** and the **phalanges.**

On page 115, Fig. 59, complete and index the prepared drawing of the human pectoral girdle and arm.

(*e*) *The pectoral girdle and wing of the chicken.* Making use of the anatomy already learned, study the pectoral girdle and wing of the chicken. Only two free carpals are present, and these are hidden in the dried ligaments. The remaining carpals are fused with three metacarpals to form a large irregular bone, the **carpometacarpus,** which consists of two parallel rods joined at the ends.

251. How many digits or fingers are present?

On page 117, Fig. 60, complete and index the prepared drawing of the pectoral girdle and wing of the chicken.

(*f*) *The pelvic girdle and hind limb of the frog.* Consult the diagram of the typical pelvic girdle and pentadactyl hind limb. The pelvic girdle is made up of the **ilium,** a [illegible] bone which extends forward from the **acetabulum,** a [illegible] like depression in which the **femur** or thigh bone fits [illegible] articulates. In the prepared skeleton, this cavity may [illegible] covered with dry **cartilage.** The **pubis** is the anter[illegible] portion of the semicircular crest which projects ventr[illegible] from the medial part of the pelvic girdle. The ischium [illegible] the posterior portion of the crest. Attention has just [illegible] called to the **femur** or thigh bone. The **tibia** and **fibula** [illegible] fused in the frog to form one bone, the **tibio-fibula** of [illegible] lower leg. The number of **tarsal bones** in the frog is grea[illegible] reduced. Two of these are much elongated; the inner one [illegible] known as the **astragulus** and the outer one as the **calcaneus.** Identify the **metatarsals** and **phalanges.**

On page 119, Fig. 61, index the prepared drawing of the pelvic girdle and hind limb of the frog.

(*g*) *The pelvic girdle and leg of man.* The pelvic girdle [illegible] made up of a single fused bone, the **innominate.** Locate the **acetabulum** and try to locate the **ilium, ischium,** and **pubis.** The bones of the leg and foot are the **femur, tibia, fibula, tarsals, metatarsals,** and **phalanges.** Identify these bones.

On page 121, Fig. 62, index the prepared drawing of the pelvic girdle and the leg of man.

(*h*) *The pelvic girdle and hind limb of the chicken.* Identify the structures present in the pelvic girdle.

252. How does this pelvic girdle differ from those previously studied?

Study the leg and foot.

253. What modifications of the tibia and fibula do you find?

Some of the tarsal bones are fused with the tibia and some with the metatarsals.

254. What name may be given to the fused tibia and tarsals? The fused tarsals and metatarsals?

255. How many digits are there?

256. Where is the ankle?

Complete and carefully index all the identified structures shown in the prepared outline drawing on page 123, Fig. 63.

Summarize your study of the limbs of the frog, man, and chicken in the chart or table found on page 125, Fig. 64.

MUSCLES

Muscles of the frog. (*Optional.*) The following study of the more easily identified superficial muscles of the frog is intended to give only a general concept of muscles, the mode of their **origin** and **insertion,** and their general function as an integral part of the adjustment mechanism. Bones and muscles are important cogs in the effecting mechanism of the vertebrate animal. The **origin** of a muscle is the region of its attachment to a fairly stable part. The **insertion** is the end attached to a movable bone.

Remove the skin from the frog and carefully separate arious superficial muscles. The external region of the ular abdominal wall is formed by the **external oblique le.** Carefully tease away a portion of this muscle and underneath, another muscle, the **transverse muscle,** e fibers run in the opposite direction to those of the nal oblique.

7. What is the function of these muscles?

the midventral line of the abdomen a thin white strip, **nea alba,** extends from the pelvic region to the sternum. ach side of the linea alba note an elongated muscle, **ectus abdominis.**

Study the muscles of the thigh and shank. On the al surface of the shank there are two rather prominent les. The anterior part of the thigh is made up of the **triceps extensor femoris.** It is attached to the tibio- a by a tendon which passes over the knee. Thus it has rigin on the pelvic girdle and its insertion on the tibio- a.

8. What is the function of this muscle?

he other prominent muscle of the thigh is the **semimem- osus.** It is the most posterior muscle on the dorsal part of the thigh, having its origin on the pelvic girdle and its insertion on the tibio-fibula.

On the ventral surface of the thigh the following muscles may be readily identified: the **sartorius,** a flat thin muscle with its origin on the pelvic girdle and its insertion in the large tendon on the knee. Lying next to the sartorius toward the middle line is a thick muscle, the **adductor magnus.** Underneath the sartorius, but visible along the anterior border, is a thin muscle, the **adductor longus.** The most posterior muscles on the ventral side of the thigh are the **gracilis major** and the **gracilis minor.** Carefully identify these muscles and determine their origin and insertion.

Study the muscles of the lower leg or shank. The calf of the leg is formed by the **gastrocnemius muscle.**

259. Determine its origin.

The insertion of this muscle is by means of the **tendon of Achilles,** which passes over the ankle and spreads out to form the sole of the foot. Anterior to the gastrocnemius and lying close to the bones on the anterior part of the leg we find the **tibialis muscles.** Between these muscles and the gastrocnemius is located the **peroneus muscle.**

On page 127, Fig. 65, draw and index the muscles in the prepared outline.

REPRODUCTION AND DEVELOPMENT

REPRODUCTION OF A PLANT

t) *An angiosperm flower.* Carefully examine the flower ished.

60. How many parts in the outermost circle or **calyx?** h part is called a **sepal.**

61. What is the color of the sepals?

he next circle of parts is called the **corolla,** and this is le up of the **petals.** The calyx and corolla together form **perianth.**

62. How many petals are there and what is their color?

he organs forming the circle inside the corolla are the **nens** or **microsporophylls.**

63. How many are there?

Note that the flower rests on an enlarged end (**receptacle**) he flower stalk (**pedicel**).

)n page 129, Fig. 66, draw a diagram (X3) of the plan of flower, showing the number and arrangement of sepals, als, and stamens.

Divide the flower into equal halves. Note that each men is made up of two parts, the thread-like or stalked tion, the **filament,** and a knob-like or dilated part, the her (**microsporangium**), which contains the **pollen grains** icrospores).

n the center of the flower is the **pistil.** The enlarged part the base is the **ovary;** the upward, more slender elonga- n is the **style;** and the tip, which is sticky, is called the gma.

264. Explain the advantage to the plant of the sticky stigma.

On page 129, Fig. 67, sketch one of the halves of the flower, showing the parts observed. Draw each part (X3).

(*b*) Cut or crush the anther of the stamen and mount some of the contents on a slide in water. Examine with the low power of the microscope. Sketch two or three **pollen grains** (**microspores**).

265. What is the function of the pollen grains?

Divide the ovary by making a median longitudinal section. Note that the ovary is made up of chambers called **locules** or **cells.** In the locules will be found the **ovules** (**megasporangia**). Note their appearance and mode of attachment to the ridge of specialized tissue, the **placenta.**

On page 129, Fig. 68, sketch the dissection to show the above points (X4).

(*c*) *Development of the pollen grain* (*male gametophyte*). Using a prepared slide, study the germination of the pollen grain. Note the **pollen tube** which grows out from the pollen grain. The pollen tube with its contents is the **male gametophyte.**

266. What is **pollination** and how is it accomplished?

267. What is the role of the pollen tube?

268. Do you find a nucleus or nuclei present in the tube?

On page 129, Fig. 69, sketch germinating pollen grains to show several stages in the development of the male gametophyte.

(*d*) *Structure of the ovule.* (*Demonstration.*) Note the two **integuments,** the **inner integument** and the **outer integument,** surrounding the central region or **nucellus.** Note the small opening where the integuments fail to meet. This opening is the **micropyle,** through which the pollen tube eventually grows. The integuments, after the fertilization of the egg, become modified to form the **testa** of the seed, or the **seed coat.**

On page 131, Fig. 70, complete the prepared sketch of the ovule to show the above points.

269. In general, what is the process of fertilization in the flower?

(*e*) (*Optional.*) Study prepared slides of lily ovaries and identify, if possible, a **megaspore,** several stages in the development of the **female gametophyte,** and the mature female gametophyte containing a fully developed **egg cell.** Especially good slides may also show some stages in **fertilization.**

(*f*) (*Optional.*) Study prepared slides of the fruits of Shepherd's purse (*Capsella*) and identify different stages in the development of the embryo.

THE FRUIT

Study each of the fruits furnished by the instructor.

270. How are they protected against lack of or excess of moisture?

271. What adaptation do you find for dissemination in each fruit?

272. What parts of the flower persist in the fruit?

On page 133, Fig. 71, sketch the specimens, illustrating the above points. Index any parts of the flower persisting in the fruit.

273. Under each sketch classify the fruit.

THE SEED

Split the hard outer protective coat or **testa** of a soaked seed, such as the Lima bean, by cutting around the outermost edge of the seed. Then spread open the halves and study the **embryo** found enclosed between the two thick **cotyledons.**

274. Is the Lima bean a monocotyledon or a dicotyledon?

The embryo plant has two feather-like leaves which, with the growing point of the stem, comprise the **plumule.** This is attached to a short stem, the **hypocotyl.**

275. What is the function of the cotyledons?

Make a similar study of the castor bean and compare it with the Lima bean.

276. In what respects are these seeds different?

On page 133, Fig. 72, sketch the opened seeds (X2) to show the above points.

GERMINATION

(*a*) Place some seeds (radish, pea, or bean) on moist filter paper in a Petri dish and allow them to germinate.

277. What causes the seed coat to break open? Explain.

(*b*) Fill two fruit jars to different heights with moist sand. Place six well-soaked peas in each jar. Seal the jars air tight. Observe daily.

278. What conclusions may be drawn from the results observed?

(*c*) Plant seeds in two receptacles filled with moist sand. Keep one in the light and place the other in the dark. Keep the temperature and moisture the same for both receptacles. Observe daily for several days.

279. What are your conclusions, based on the results observed?

(*d*) Plant six seeds in each of two containers filled with moist sand. Place one container in the refrigerator and the other in the laboratory where it is exposed to ordinary room temperature. Observe daily for several days.

280. What conclusions do you draw from your observations?

DEVELOPMENT OF AN ANIMAL

Recall that eggs develop in an ovary. The eggs are expelled from the ovary, move down the oviduct, and, in some animals, pass into a cloaca. Eventually they are laid. Sometimes the eggs are fertilized within the animal and remain within the mother in an organ called the uterus. Here the young develop and, after a certain period, leave the uterus, i.e., are born.

The spermatozoa develop in the testis (plural, testes) and are carried from the testis by the sperm duct or vas deferens (plural, vasa deferentia) which may open into a cloaca. In many instances the vas deferens leads into the sexual organ, the penis.

Review the anatomy of the reproductive apparatus of the frog and the cat from sketches and demonstration specimens.

The early developmental processes of different animals, particularly the vertebrates, are very similar. The cleavage of the egg and early development of the frog serve quite well to show in a very general way the process that takes place in all animals.

(*a*) *The unsegmented egg.* From the instructor, or assistant, procure an unsegmented frog egg and study it with a hand lens or the lowest power of the microscope. Note the **animal hemisphere** (the black part of the egg) and the **vegetative hemisphere** (the white part of the egg).

281. How many layers of **jelly** surround the egg?

282. Are these layers of the same thickness?

(*b*) *Two-cell stage.* Note that the egg (zygote) is soon divided into approximately equal halves or **blastomeres** by the **cleavage furrow.**

283. What is the location of the cleavage furrow with erence to the poles?

On page 135, Fig. 73, make a sketch of this stage without jelly. Make the drawing approximately 3 cm. in meter. Index the **animal pole, vegetative pole, cleavage row,** and **blastomere.**

(c) *Four-cell stage.* A second cleavage furrow is now sent and there are four blastomeres.

284. How is the second cleavage furrow located with erence to the poles?

(d) *Twelve- or sixteen-cell stage.*

285. Are there as many cells in the region of the animal le as there are in the region of the vegetative pole?

On page 135, Fig. 74, make a sketch of this stage. Use e same dimensions as in the previous drawing.

(e) *Blastula.* Study the prepared slide of the frog astula. Identify animal pole, vegetal pole, blastocoel, d blastomeres.

286. Are all the blastomeres of the same size?

On page 135, Fig. 75, make a sketch (about the size of a ver dollar) to show these regions. Do not attempt to show llular structures.

(f) *Early gastrula.* The cells have become smaller and ore numerous and are now arranged in a hollow ball of lls known as a **blastula.** The area made up of the black lls grows more rapidly than the lighter area and, consequently, the white cells begin to be tucked up into the ollow blastula. This results in the formation of a crescent-haped line opening into the egg but *not* into the blastula avity. This line is the **blastospore.** The blastula has now een transformed into the **early gastrula.**

(g) *Late gastrula.* This invagination or tucking in of ells continues until the white area is reduced to a small ircle of white cells, which make up the **yolk plug.** The olk plug is all that is visible externally of the vegetative alf of the egg. This is known as the **late gastrula** stage.

(h) *Neural groove.* Coincident with, or immediately ollowing, the formation of the yolk plug, two continuous olds or ridges are formed. These are the **neural folds.** Between these folds is a depression, the **neural groove.** Note that the folds are wider at one end of the embryo han at the other.

287. What forms from the wide end of the folds?

On page 135, Fig. 76, draw this stage of development with neural folds directed toward you and index the points observed.

(i) *Study of neural fold stage.* Study the prepared slide of the neural fold stage of the frog. Note the neural groove with the two raised neural folds.

288. What will the neural folds form in the adult?

Underneath the neural fold will be seen the beginning of the notochord. Identify the **archenteron.**

289. What cell layer forms the archenteron?

Between the archenteron and the outer **ectoderm** will be seen the lateral sheets of **mesoderm** which later split into an outer **somatic layer** which is in contact with the ectoderm and an inner **splanchnic layer** which is in contact with the **entoderm.** Note the space between these two layers.

290. What is the name of this cavity?

The ectoderm and somatic mesoderm make up the **somatapleure,** and the entoderm and splanchnic mesoderm form the **splanchnopleure.** On page 135, Fig. 77, make a sketch (about the size of a silver dollar) to show these regions. Show the extent of the various lines and structures mentioned above in outline only. Do not put in cellular structures. Color ectodermal structures blue, mesodermal structures red, and entodermal structures yellow.

(j) *Early larva.* The developing animal or embryo now has a prominent **tail** and somewhat rounded **body** because of the presence of some unabsorbed **yolk.** The thickened **gill plates** may be seen at the sides of the head.

(k) *Tadpole.* (Several months to a year after fertilization of the egg.) Note the prominent **tail** around which is the membranous **fin.** The tail is divided into V-shaped segments or **myotomes.** These are bundles of muscles, perhaps a remnant of primitive segmentation. Note the **eyes, nasal pits, mouth, intestine,** and **legs.**

291. What pairs of legs do you find?

292. Are toes present?

Complete the outline of the tadpole, on page 137, Fig. 78. Index carefully.

LIFE HISTORY OF AN INSECT

Using the material furnished, study the life history of a representative insect.

293. What is the first motile stage in the life history?

The next stage in the life history is the **pupa** or **chrysalis** stage.

294. How does a chrysalis differ from a **cocoon?**

Study the chrysalis.

295. Of what is the cocoon composed?

Examine an adult butterfly or moth.

296. How many body regions has it?

297. How many legs does it have?

298. How many antennas does it have?

HOMOLOGY AND ANALOGY

In different animals, those structures which have a similar embryonic origin and whose topographic location on the animal is fairly similar but whose final form and function may be the same or different, are said to be **homologous.** Theoretically these structures or organs are supposed to

have come from a rather generalized structure possessed by some common ancestor. Analogous organs or structures are those whose function is similar but whose embryonic origin is different.

(*a*) *Homologous structures. Embryonic vertebrate limbs.* Examine and compare the limb buds of the early and late tadpole stages of the frog.

299. How do the hind-limb buds of the two stages differ?

Examine and compare the limb buds of a chick embryo at about 72 hours of incubation with those of an embryo at approximately 120 hours of incubation. Identify the **head, eyes,** and **limb buds.**

300. How do the fore limbs differ from the hind limbs?

301. How does the early stage of the chick differ from the early tadpole stage of the frog?

302. Would you say that these limb buds have a similar origin?

(*b*) *Analogous structures.* Structures or organs of diverse origin and structure, yet carrying out the same function, are said to be analogous.

Compare the wing of an insect with the wing of a bird or a bat.

303. Do you notice any similarity in structure?

304. Would you suppose their embryonic origin to be similar? Why?

305. What is the function of both the above-named organs?

HEREDITY

MITOSIS

Examine the prepared slides of both plant and animal cells, such as those in the root tip of onion or *Tradescantia*, or the eggs of *Ascaris*. On page 139, Fig. 79, identify and sketch **prophase, metaphase, anaphase,** and **telophase** stages of mitotic cell division.

306. How does the spindle of a plant cell differ from that of the animal cell?

MATURATION OF GERM CELLS

(*Demonstration experiment by instructor.*) Recall that sometime before fertilization takes place the germ cells of animals and plants undergo a process of **maturation (meiosis),** by which the chromosome number in the germ cells is reduced to one-half the original number. In some animals, the processes of maturation and fertilization occur almost simultaneously. This is true of the worm, *Ascaris*, the maturation of whose female germ cells we are now ready to study.

Examine a dissected specimen of *Ascaris* and ask the instructor or assistant to demonstrate the internal anatomy of the animal. In different sections of the uterus the eggs are in various stages of maturation. The regions of the uteri nearest the ovaries will show the early or beginning stages, whereas those farther down will show later stages. These different regions of the uterus are mounted on slides. The instructor will indicate on the slides where the different regions may be found.

To aid in understanding maturation you will find diagrams showing the chromosome behavior accompanying the directions and descriptions of the actual process.

In the sections note the heavy walls of the uterus containing the large round **oocytes** or perhaps later stages. In the first sections studied, observe the dark, somewhat triangular bodies, the **spermatozoa.** Some spermatozoa may have already penetrated the oocyte; others may be seen among the oocytes in the uterine cavity.

(*a*) *Uppermost row of sections.* Note the **primary oocytes** and **spermatozoa** (Fig. B.).

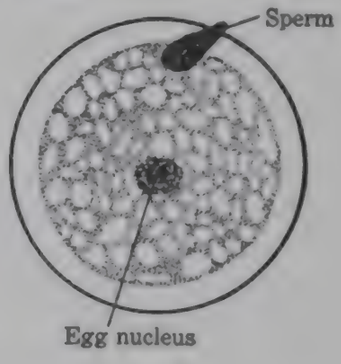


FIG. B.

(*b*) *Second row of sections.* Oocytes in the first maturation division. Chromosomes in **synapsis** and divided to form **chromatids** give the appearance of quadruple bodies or **tetrads.** Note the somewhat clear oval area around the tetrad. This is the **spindle** (Fig. C).

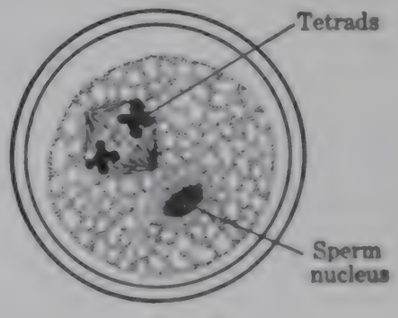


FIG. C.

307. How many groups of tetrads are there?

308. How many chromosomes are there in the cell? (An additional nucleus, that of the spermatozoon, may be seen in the cell.)

(*c*) *Third row of sections.* The oocytes are now surrounded by a thick shell-like membrane. Find the spindles and note the arrangement of the chromosomes, the dyads,

he spindle. This is one-half of a tetrad. Note in some imens a black body just under the membrane. This is **first polar body** (Fig. D).

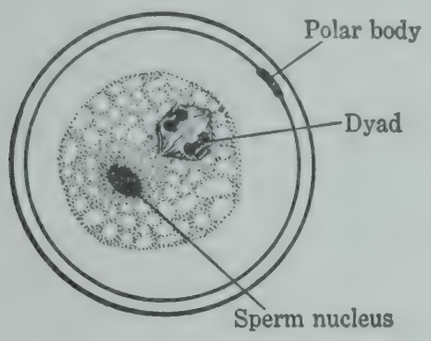


Fig. D.

309. How many chromosomes are there in the first polar dy?

310. How many chromosomes are there in a dyad?

311. Why are polar bodies not seen in all the oocytes?

(*d*) *Fourth row of sections.* Note that only two single romosomes remain in the cell. The other two appear in e **second polar body.** Two polar bodies may now be visi- e in some of the eggs.

312. What happens to the polar bodies?

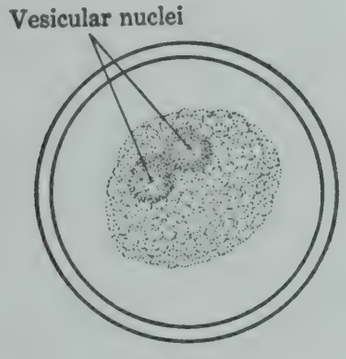


Fig. E.

In some of the eggs two large **vesicular nuclei** may be een in which the chromatin is scattered in the form of ranules (Fig. E).

313. What are these two nuclei? These two nuclei now nite (fertilization).

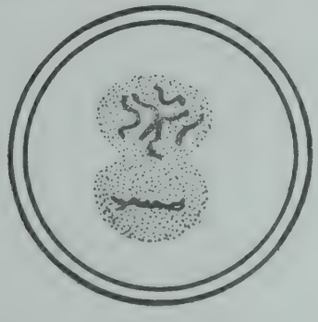


Fig. F.

(*e*) *Fifth row of sections.* The ovum is now fertilized and he zygote is undergoing cleavage (Fig. F).

314. How many chromosomes are now in a cell?

GENETICS

Many of the modern principles of heredity have been gleaned from experiments with the fruit fly, *Drosophila.* Completion of the life cycle in these insects requires only a comparatively short time. Moreover, they are easily reared in the laboratory. The female flies are readily recognized since they are usually stouter than the males and have a broader abdomen. Another recognition mark which may be used is the presence on the female of a white area extending along the under side of the abdomen back almost to its tip. At the end of the white area is a small black speck on the ovipositor. In the male this light area is reduced by a crescent-shaped black region on the under side of the tip of the abdomen. Near the anterior edge of the concave side of the crescent is a small brown protuberance, the external male genitalia.

In mating the flies, care must be taken to use only virgin females. There is no objection to mating several virgin females and males in one bottle, provided all the flies of the same sex are alike genetically. Since the rearing of the flies must be cared for by the laboratory instructors, only the following general principles of technique need be observed by the student.

When preparing for an experiment, remove all adult flies from a culture bottle. Replace the stopper of the bottle and set it aside for several hours, at the end of which time the adults will begin to emerge from the pupae. Females may then be regarded as virgin and should be isolated by removal to another bottle. This may be done by inserting a wad of cotton containing a few drops of ether, thus etherizing the flies. After the flies are etherized, the cotton should be removed. Living flies may now be transferred from one bottle to another by remembering that *Drosophila* is positively phototropic. Thus, if the bottom regions of the bottles are darkened, the flies will move to the light end. Then hold the mouth of another bottle over this light end and the flies will enter it. With these few simple directions in mind, make the following crosses.

(*a*) *Monohybrid cross. Drosophila.* Place several virgin females, genetically pure for the character selected by the instructor, in a vial with some males, either dominant or recessive for this character. Offspring will appear about ten days later. Observe their characteristics.

315. Are they all alike?

316. Which parent do they resemble?

Set up a fresh culture with several females and males of this generation. In this case it is not necessary to use virgin females. About ten days later the next generation, or F_2 generation, will appear.

317. What characters appear in the flies of this generation, and in what proportion?

(*b*) *Monohybrid cross. Corn.* A number of ears of corn will be furnished, some of the parental generation (*P*), some

of the F_1 generation, and some of the F_2 generation. In this cross, a plant from a strain that produces red grains is crossed with a plant from a strain that produces white grains. Note the ears of the P_1 generation.

Now examine the ears of corn of the F_1 generation.

318. What is the color of the grains?

319. Which color is dominant and which is recessive?

When plants grown from the grains of corn from this F_1 generation are crossed, an F_2 generation is produced, the plants of which may bear ears of corn. It should be noted, then, that each individual grain in an ear of corn represents a plant.

320. Count the grains of corn of each color and determine the ratio.

321. What do you conclude are the dominant and recessive characters?

322. How does this ratio compare with the ratio obtained in the F_2 generation of flies?

(*c*) *Dihybrid cross. Drosophila.* (*Optional.*) In dihybrid crosses, two pairs of genetic factors are involved. Put several virgin females, genetically pure for the two characters selected, in the bottle with several selected males having the contrasting characters. After ten days observe the offspring.

323. Are the individuals all alike?

324. Which characters would you say are dominant?

Now set up a fresh culture with several females and males of this generation. In this case it is not necessary to use virgin females. About ten days later the F_2 generation will appear.

325. What characters appear in the offspring, and in what proportion?

326. How does this ratio differ from the ratio obtained in the monohybrid cross?

327. Compute the hypothetical number of the different types of flies.

328. How does this compare with the actual ratio found in the experiment?

(*d*) *Sex linkage.* (*Optional.*) Sex linkage in animals occurs when the factors for a certain character or characters are located in the X-chromosomes, which are associated with sex. As you may recall, in *Drosophila*, the female has two X-chromosomes whereas the male has an X-chromosome and a Y-chromosome.

Mate some females homozygous for red eye-color with males homozygous for white eye-color.

329. What type of offspring appear in the F_1 generation?

Set up a fresh culture using several females and males of this F_1 generation. About ten days later the F_2 generation will appear.

330. What types of flies are found in this F_2 generation?

331. What is the relation between the sex of the flies and the eye characters?

Now make a cross, using females homozygous for white eye-color with males homozygous for red eye-color.

332. What kind of individuals are found in the F_1 generation?

333. Do you note any relation between eye-color and sex?

Now set up a fresh culture containing several females and males of this F_1 generation. About ten days later the F_2 generation will appear.

334. What characters appear in the offspring, and in what proportion?

335. How does this ratio differ from the ratio in the monohybrid cross?

336. Compute the hypothetical number of different types of flies. How does this compare with the actual ratio found in the experiment?

THE ANIMAL KINGDOM. TAXONOMY

In attempting to classify animals, Linnaeus and later scientists have arranged them in separate groups or divisions. All those animals having certain characteristics peculiar to them alone are placed in the same group. The group consisting of animals having the fewest characteristics in common is called a phylum. Phyla are divided into sub-groups called classes. Classes are distinguished from one another in the same way as phyla, but by means of characters less fundamental and less primitive than those used in separating phyla. The following studies are designed to give some knowledge of the most important phyla and some of their representative animals.

PHYLUM PROTOZOA

Ameba. Class Sarcodina. The ameba has already been studied in exercise on page 3. Review this exercise.

a. Entameba histolytica. Examine specially prepared stained slides of this protozoan.

337. How does it differ from the free-living ameba previously studied?

338. What part of the host is infected by this parasite?

b. Other Sarcodina. Examine the slides furnished you or those under the demonstration microscopes for other types of Sarcodina.

339. Describe each of the forms observed.

340. What structure is common to all Sarcodina?

Paramecium. Class Infusoria. (*a*) Procure some culture material from an assistant and study it microscopically in the same manner as you did the ameba except that much light must be used. There will probably be a number of different animals in the culture, but the large slipper-

ed animals are paramecia. Note carefully the general e of the body.

1. By observing the paramecium moving about, can determine whether or not one end is usually directed ard?

2. How would you designate the two ends of the nal?

3. How does the animal differ from ameba in shape? ote carefully the movement of the animal.

4. Describe the locomotion of paramecium.

ote the concave depression in one side of the animal. s is the **oral groove.**

5. How far does the oral groove extend?

) Now study a paramecium under the high power of microscope. Select an animal that is fairly quiet. Some he animals may be trapped in small droplets of water, these must be studied at once for they soon assume ormal shapes and die.

46. Does the animal have **ectoplasm** and **endoplasm?**

thin **cuticle** or **pellicle** may be seen covering the animal. jecting from this layer are the **cilia.** These are best seen ng the edge of the animal. Under the cuticle there is a er made up of minute rod-like bodies which lie perpenular to the surface and parallel to each other. These are **trichocysts.**

47. What is the function of the cilia?

Now examine carefully the internal structure of the amecium.

48. Are **food vacuoles** present?

49. What is the rate of contraction of the **contractile cuoles?**

Study a prepared slide and note the two nuclei present, e large **meganucleus** and the smaller **micronucleus.** Exine the prepared slide carefully and see if you can find y paramecia undergoing fission.

350. Is this sexual or asexual reproduction?

Two paramecia may become united in the region of their al grooves. Such animals are in conjugation. Try to d some conjugating paramecia.

351. Is this sexual or asexual reproduction?

352. How does the nuclear behavior differ in these two ocesses?

On page 141, Fig. 80, make a sketch of the paramecium, ing the prepared outline and filling in all the structures served thus far.

(c) *Feeding.* (*Optional.*) To some water on a slide containing paramecia, add some finely powdered carmine or rbon. Observe after a half-hour. Water must be added intervals to prevent the drying of the culture.

353. Has any of the carmine or carbon been ingested?

354. How is food distributed in the animal?

(d) *Protection.* (*Optional.*) To some water on a slide ontaining paramecia, add a drop of safranin solution or picroacetic acid. Now observe that each animal is surrounded by a network of long threads which have been shot out from the trichocysts.

355. How might this reaction protect the animal?

Class Sporozoa. These are parasitic protozoa. One of the most common sporozoans is the parasite *Gregarina,* often found in the larva of the adult meal beetle, *Tenebrio.* Remove the digestive tract, mount on a slide and examine under low power. The gregarines, if present, are dark colored bodies, several times longer than they are wide.

If these parasites are present, tease apart portions of the digestive tract in a drop of normal salt solution. Then study under high power.

356. Describe the organism.

357. Do the organisms move?

On page 143, Fig. 81, draw the parasite.

Demonstration. On the demonstration microscope study slides of the malarian parasite, *Plasmodium.*

358. What stages are present?

On page 143, Fig. 82, make a sketch of the stage or stages of the malarian parasite observed.

Class Flagellata. On the demonstration microscopes, study various parasitic Flagellata.

359. What are the effects on the host of each of these forms?

On page 143, Fig. 83, sketch the flagellates observed.

Other Protozoa. (*Optional.*) Study drops of water and debris from other cultures in the laboratory or bring some pond scum to the laboratory. Remember that Protozoa are single-celled animals. Some of the forms which may be seen are:

(1) *Vorticella:* an animal with a somewhat bell-shaped body attached to the end of a rather clear slender **stalk** which contains muscle-like fibers or **myonemes,** by which the stalk may be contracted.

360. Do you find any **cilia? Food vacuoles? Contractile vacuoles?**

(2) *Stentor:* an animal which resembles *Vorticella* somewhat but lacks a stalk. It is often attached.

361. What is peculiar about its cilia?

(3) Other Protozoa which may be seen. Some of these are illustrated on page 213, Fig. 156.

PHYLUM PORIFERA

These animals are aquatic and mostly marine. They are usually **radially symmetrical.**

Scypha (*Grantia*). *Class Calcarea.* Study a specimen of *Scypha.*

362. What is its shape?

Note that the animal is attached at the **base.** At the other end will be seen a collar of straight needle-like **spicules**

which surround an opening, the **osculum.** Examine the animal for indications of budding.

(*a*) Study the longitudinal section of *Scypha*. Using a hand lens, note the central cavity or **spongocoel,** which opens to the exterior by means of the **osculum.** The thickened wall of the animal is traversed by small **canals.**

363. What is the purpose of these canals?

Some of these canals open into the spongocoel by pores known as **internal ostia.** The openings seen in the spongocoel are the internal ostia.

On page 145, Fig. 84, complete the sketch of a longitudinal section of *Scypha*.

(*b*) Examine a cross section of *Scypha*, and note that many cells are present. Note that transparent needle-like bodies called **spicules** may be present. The spicules may be studied from prepared slides.

364. What is the function of these spicules?

Examine the slide carefully and note how many kinds of spicules you find. The cross section will be seen to consist of a central cavity, the spongocoel, from which radiate the **canals.** Note that these are of two kinds: **excurrent canals** which empty into the spongocoel through the **internal ostia,** and **incurrent canals** which open by **pores** to the exterior and not directly into the spongocoel. The excurrent canals communicate with the incurrent canals through very minute openings which probably will not be seen.

On page 145, Fig. 85, complete the drawing of a cross section and fill in one-fourth in detail. Show by arrows the course of the water through the animal. Also make sketches of the different types of spicules.

Other Porifera. Examine the different specimens of sponges displayed.

365. What characteristics do they have in common?

PHYLUM COELENTERATA

These are aquatic animals, mostly marine. A common fresh-water form is hydra.

Hydra. Class Hydrozoa. This most common fresh-water coelenterate is often found on the sides of jars of water containing leaves, algae, and water plants taken from pools and sluggish streams. In nature the animals are found on submerged rocks, debris, and aquatic vegetation.

(*a*) Place a specimen in a watch glass in water. Place the watch glass under the lowest power of the microscope or study with a hand lens.

366. Describe the shape and color of the animal.

The **mouth** is located at the summit of an elevation called the **hypostome.** Surrounding the mouth is a circle of **tentacles.** Place a daphnid or a *Cyclops* near the tentacles of the hydra.

367. Observe and describe how a hydra gets its food.

368. How is a hydra attached?

369. What part of the animal seems to be most sensitive?

370. What kind of symmetry does a hydra have?

371. How many tentacles are there on your specimen? On your neighbor's specimen?

372. Does your specimen show any evidence of budding?

On page 147, Fig. 86, make a sketch of the expanded animal and index carefully.

(*b*) Study a prepared slide of the whole mount of a hydra or place your specimen on a slide in some water. Place one or two small pieces of broken glass in the water to support the cover glass. Notice that the animal is covered with an almost transparent layer, the **ectoderm,** underneath which may be seen an inner layer, the **endoderm.**

Under the microscope, examine the ectoderm of one of the tentacles. The large, rounded clear cells contain the **nematocysts.** Carefully add a drop of safranin to the water under the cover glass.

373. What happens to the nematocysts?

374. What is the function of the nematocyst?

375. Do you see more than one kind of nematocysts?

On page 147, Fig. 87, draw some exploded nematocysts.

(*c*) Study prepared slides containing cross sections of a hydra. Identify the **ectoderm, endoderm,** and the central **gastrovascular cavity.** Between the ectoderm and the endoderm is a third non-cellular layer, the **mesoglea.**

376. How does the ectoderm differ from the endoderm?

377. How thick is the mesoglea?

378. What stage in the development of the frog does the body structure of a hydra resemble?

Complete and index accurately the drawing of the cross section of a hydra on page 147, Fig. 88.

(*d*) *Regeneration.* (*Group experiment.*) Cut several living hydras into two or more pieces, in any manner you may choose. Using a clean medicine dropper, transfer the pieces to a clean sterilized stender dish containing fresh water (untreated chemically) that has been boiled and aerated by shaking. Cover the dishes and set them aside in a place where the temperature is moderate (20° C.) and fairly constant. Observe after the lapse of three or four days, and make continued daily observations until no further development is noticed.

379. Describe any changes that may have taken place in the cut pieces used in this experiment.

Obelia. Class Hydrozoa. This animal grows in plant-like colonies on wharves and rocks in salt water. Examine the specimens on the supply table.

(*a*) Fragments of colonies have been stained and mounted on slides for study. Study a prepared slide under the microscope and note at the end of the branches **hydranths** or zooids bearing **tentacles.** Each hydranth is enclosed in a

ke sheath or **hydrotheca** which, you will note, is a nuation of the membranous covering of the whole y, the **perisarc.** In the expanded hydranth, note an ated projection in the midst of the tentacles, the stome, in which is found the **mouth.** Note on the cles the raised **rings of nematocysts.**

). What animal previously studied has had nemato- ?

1. Compare the hydranth of *Obelia* with that of *Hydra.* e fleshy continuation of the hydranth into the stalk is coenosarc. The cavity in the body of the hydranth, the **gastrovascular cavity,** is continuous through the osarc. The coenosarc is surrounded by an outer trans- nt sheath, the **perisarc.**

) Sometimes in the angles between the hydranth and nain stalk are found **gonosomes,** urn-shaped structures, outer sheath of which is called the **gonotheca.** The y core of the gonosome is the **blastostyle,** on which are d small rounded wheel-like projections, the **gonophores** nedusae. These medusae detach themselves, swim out he gonosome, and have a free-swimming existence.

32. Would you say that *Obelia* in this stage reproduces ually or asexually? Why?

omplete and carefully index the prepared drawing of *lia* on page 149, Fig. 89.

c) The minute medusa which is freed from the gonosome *Obelia* very closely resembles the larger medusa *Gonione-* s in structure, mode of life, and reproduction. For this son *Gonionemus* will be studied. However, it must be nembered that *Gonionemus* is not the medusa of *Obelia.*

Gonionemus. Class Hydrozoa. (*a*) Place a specimen of *nionemus* in water in a watch glass and study under the nd lens. *Gonionemus* resembles somewhat the shape of umbrella. The outer convex region is called the **exum-** ella and the concave region is the **subumbrella.** On the der side of the animal will be found a thin membrane, the lum, which is perforated in the center. Hanging down the center is the pouched **manubrium** with a **mouth** at lower end. Four **radial canals** extend out from the base the manubrium to the **circular canal** around the rim of e subumbrella.

383. What is the function of these canals?

384. Describe the arrangement of tentacles and nema- cysts in *Gonionemus.*

385. What type of symmetry does *Gonionemus* have?

(*b*) Examine the animal with the lowest power of the croscope or with a hand lens and note, at a short dis- nce from the free end of the tentacle, a circular **adhesive** d or **adhesive organ.** Between the bases of the tentacles ere are somewhat transparent saccular outgrowths called hocysts. In these there are opaque spots which are cal- reous bodies called **lithites.** These organs are probably ed in maintaining equilibrium. Note the reproductive organs or **gonads** underneath the radial canals and attached to them.

386. Would you say that the medusa reproduces sexually or asexually?

The zygote or the medusa of *Obelia* develops into the colonial animal previously studied.

Carefully complete and index the prepared drawing of *Gonionemus* on page 149, Fig. 90.

387. Construct a diagram showing the alternation of generations in *Obelia.*

388. What is alternation of generations?

Other Coelenterata. Examine demonstration specimens of other animals belonging to this phylum.

389. Are they radially or bilaterally symmetrical?

390. Would you say that radial symmetry is characteristic of the members of this phylum?

PHYLUM PLATYHELMINTHES

These animals may be either free-living in water or earth or may be parasitic on other animals.

Planaria. Class Turbellaria. This animal is found in springs and small streams under rocks, leaves, or decaying wood. It is not parasitic. Study the living animal and note how it moves.

391. Explain how it moves.

There is a rather definite anterior end on which will be found two **eye spots.** In the median, posterior region of the body on the ventral side will be seen the short tubular **pharynx** enclosed in the **pharyngeal chamber.** The pharynx can be everted from the body for sucking food.

Study a prepared slide of a whole mount of planaria. It will be seen that the pharynx opens into the dark-colored **intestine** which consists of three main branches: an anterior median branch and two lateral posterior branches. A number of small sacks or **diverticula** come off the main branches of the intestine.

(*a*) *Regeneration.* (*Group experiment.*) Cut several living planarians into two or more pieces, in any manner you choose. Transfer the pieces to a clean finger bowl or stender dish containing fresh water (untreated chemically) that has been aerated by shaking. Cover the dishes and set them aside. Observe after the lapse of five days and make continued daily observations until no further development is noticed.

392. Describe any changes that may have taken place in the cut pieces used in this experiment.

Flukes. Class Trematoda. Various species of flukes are parasites in most vertebrate animals including man. Certain forms may be secured from the lungs or the coelom of the frog. According to Chandler (Asa C. Chandler, *Introduction to Parasitology,* John Wiley & Sons, p. 240), "Few animals have more intricate and highly specialized repro-

ductive systems than they possess, and their life histories are so marvelously complex as to tax our credulity."

Examine specimens of living or preserved flukes and locate the **mouth** and **suckers.**

393. How do these animals differ externally from planaria?

Now study the stained prepared slide of some fluke such as *Clonorchis.* Note the **mouth** which leads into the short **pharynx** from which branch the two laterally placed **intestines** or **intestinal caeca.** Note the clear tubular **excretory canal** which opens at the posterior end through the **excretory pore.**

394. Compare the digestive tract with that of planaria.

These animals are hermaphroditic. In the anterior region of the animal, note the small irregular oval brownish **eggs** in the irregularly branching **uterus.** In the posterior regions will be seen irregular branching tubes, the **testes.** In the lateral regions of the animal will be seen a number of round bodies resembling "bunches of grapes." These are the **yolk glands.** The reproductive system of these animals is very complicated and can be worked out best only by the assistance of the instructor.

On page 151, Fig. 91, complete the drawing and carefully index the parts observed.

These animals have a very complicated life history involving sometimes as many as two or three different hosts. The egg of the flukes of one group (Digenea) develops into a **miracidium** stage resembling the Ciliata in Protozoa. The miracidia may encyst in a snail where they may change into a stage known as the **sporocyst.** Sporocysts in turn may grow into another form or stage known as a **redia.** A redia eventually may produce a new type, or last stage, called a **cercaria,** in the cycle before the final host is attacked.

Examine the slides on the demonstration microscopes showing these stages.

On page 153, Fig. 92, sketch these stages, index them and indicate their order of appearance in the life cycle of the fluke.

Demonstration. Examine other species of flukes under the demonstration microscopes.

395. List the host and intermediate hosts of each of the flukes examined.

Tapeworms. Class Cestoda. Like the flukes, these animals are parasitic. They also have a life cycle which usually involves an intermediate host. Tapeworms are colonial animals; each **proglottid** represents an individual zooid. Study the adult worm. Note the **scolex,** if one is present. The scolex anchors the tapeworm in the intestine of the host.

396. What structures do you observe on the scolex which may adapt this structure for the function just mentioned?

397. Which proglottids are the more mature, those nearer the scolex or those farther away?

Compare the various types of tapeworms which may be available as demonstration specimens.

Following the diagrammatic sketch of the proglottid shown on this page, identify as many of the structures as possible on the prepared slide.

On page 153, Fig. 93, make a drawing of a mature proglottid. Show only those structures which you have been able to identify in the specimens in the laboratory.

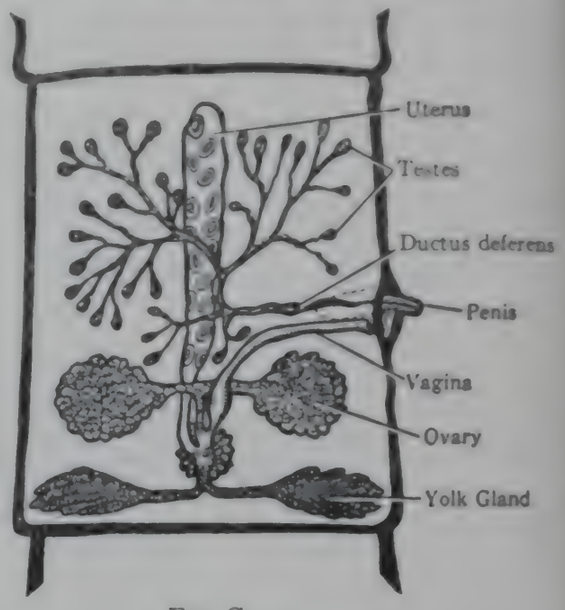


FIG. G.

The zygotes develop into hooked embryos which enter the digestive tract of the secondary host where they may enter the blood stream and be carried to the muscles of the host. Here the embryo develops to a stage known as the bladder worm or **cysticercus.**

Examine a slide of a cysticercus.

398. Describe this stage, keeping in mind the structures of the adult tapeworm.

On page 153, Fig. 94, draw a cysticercus.

PHYLUM NEMATHELMINTHES

These are round, unsegmented worms. Many members of this phylum are parasitic, and man and his domestic animals harbor certain of these parasites. We shall study the anatomy of *Ascaris,* a large roundworm found parasitic in many domestic animals and man.

Ascaris. (*a*) *External anatomy.* Study the preserved specimen furnished you.

399. Is the worm segmented like an earthworm?

With the aid of a hand lens note, at the one end of the worm, the **mouth** bordered by a **dorsal lip** and two **ventral-lateral lips.** The **anus** is found on the ventral side near the posterior end. If the animal is a male, bristly **penial setae** will project from the anus. In the female, the **genital pore** will be found in the mid-ventral line about one-third of the worm's length from the anterior end.

(*b*) *Internal anatomy.* Pin a specimen, dorsal surface up, in a dissecting pan. Cover with water. With the scissors cut through the dorsal body wall and extend the incision the entire length of the animal. Spread the walls of the

mal and fasten with pins in the dissecting pan. Note the d outer layer of **cuticle** with which the animal is covered.

400. Why would *Ascaris* have this tough protective layer?

Running the length of the animal will be found the some- at flattened **digestive tract.** At the anterior end note the uscular **pharynx** and at the posterior end the **rectum.**

401. Why would you expect to find such a simple diges- e system in *Ascaris*?

The reproductive system of the female is made up of two **aries** and **oviducts** consisting of many coiled tubes. Each iduct joins a tube of somewhat larger diameter, the **erus.** The two uteri unite to form the **vagina** which opens the outside through the **genital pore.**

If the animal is a male, there will be present a single coiled be. The following regions of the tube should be identified. he **testis** is the region where the tube is smallest in diame- r. This leads into a **ductus deferens,** one region of which expanded to form the **seminal vesicle.** This leads into a mewhat more muscular expanded region, the **ejaculatory uct,** which opens into the **cloaca.**

On page 155, Fig. 95, complete the drawing showing the ternal anatomy of *Ascaris*.

(*c*) *Cross section of Ascaris.* Note the thick outer layer of uticle underneath which will be found a thin layer of **ncytial epidermis.** Under this layer will be seen the mewhat feathery layer of **muscles.** In this layer note he cross sections of the **dorsal** and **ventral longitudinal nes** and the **lateral lines** near which will be seen the cross ections of the lateral **excretory ducts.** Note the cross sec- ion of the **digestive tract.** This is readily identified by its ning of columnar epithelium. If the animal is a female, ross sections of the **ovaries** and **oviducts** will be seen. hese have very small lumina. Cross sections of the **uterus** nay be present. The cross sections are much larger than he ovaries or oviducts, the walls are "thinner" and often ections of **eggs** are present in the uterus.

On page 157, Fig. 96, complete the drawing of the cross ection of *Ascaris*.

(*d*) *Trichina.* Study the specimen of trichina encysted n the muscles.

402. How does a person become infected with trichina?

(*e*) *Demonstration.* On the demonstration microscopes bserve other types of parasitic roundworms.

403. List the types observed and prepare table to indi- cate the host, intermediate hosts, and mode of infection.

PHYLUM MOLLUSCA

In the specimens furnished, note that the body is soft and unsegmented. Examine the clam and the squid (*Loligo*).

404. Is the body bilaterally symmetrical?

Locomotion is usually effected by a fleshy, muscular **foot.** In the squid the foot has been transformed into a sort of head with the **mouth** in the center and the edge fringed with **tentacles.** Notice the foot of the snails in the aquarium.

405. What is its shape?

The body usually possesses a **mantle** which is often a thin membranous sheet of tissue. In the squid the mantle may be a thick body covering and an organ of locomotion. The **shell** of the mollusk is secreted by the mantle. Note that the members of this phylum, with the exception of the octopus and the squid, have the body supported by an external framework. This is an **exoskeleton.**

The clam. Class Pelecypoda. (*Optional.*) The animals most suitable for this study are the hard-shelled clam (*Venus*) or the fresh-water mussel (*Unio*). If possible, study the living animal.

406. How does it move?

Place some carmine particles in the water where the **siphons** are extended.

407. Where does the water enter and leave the shell?

408. Of what advantage is this circulation of water?

(*a*) Study the shell of the animal and note that the two valves are held together by a dorsal hinge **ligament.**

409. How can you distinguish between the right and left valves?

Note the concentric **lines of growth.**

410. Explain how these are formed.

Observe the swelling on each valve, the **umbo,** the tip of which is the **beak.**

If you so desire, sketch a valve to show these points.

Open the valves by inserting a knife blade between them and cutting the muscles which close them. These are the **adductor muscles.**

411. Why do the valves gape when these muscles are cut?

Notice that the soft parts of the animal are covered by the **mantle,** a sheet of tissue that is thickened along the ventral border of the valves. The mantle is fused and thickened posteriorly where it forms the **siphons.**

412. What is the function of the siphons?

413. Are the mantle lobes fused along the ventral border?

414. How would it be possible for the animal to extend the siphons beyond the shell?

415. How could the siphons be pulled into the shell?

Study the interior of one of the valves. The inside of the shell is made up of the smooth pearly or **nacreous layer.** Note the **scars** where the **anterior** and **posterior adductor muscles** were attached.

416. Can you find additional scars near the adductor muscle scars where the foot muscles were attached?

The adductor muscle scars are connected by the **pallial line** which has a posterior indentation, the **pallial sinus.**

417. Account for these markings.

Observe the roughened anterior **cardinal teeth** and the more posterior **lateral teeth.**

418. What is the function of the teeth?

If you wish, draw the internal view of a valve.

(*b*) Now remove the mantle of one valve and continue your study of the viscera of the mollusk. Note the hard muscular ventral **foot.** This is composed of muscle fibers crossing in various directions. One pair of **foot muscles** is attached to the anterior region of the valve and another to the posterior.

419. How is the foot extended from, and retracted into, the shell?

The **gills** are striated, plate-like organs in the **mantle chamber.**

420. How many pairs of gills are there?

421. How are they attached?

422. What is the function of the gills?

Posterior to the dorsal border of the anterior adductor muscle, on each side of the visceral mass, is a pair of triangular folds, the **labial palps.** The two outer palps are united dorsally to form a small fold like an upper lip, underneath which is the **mouth.** The lower lip is formed somewhat similarly by the two inner palps.

If a live animal is available, remove a small portion of a labial palp or gill and mount it on a slide in some of the liquid taken from the mantle cavity. Examine under the microscope and note the action of the **cilia** covering the surface of these organs.

In the dorsal region, somewhat anterior to the posterior adductor muscles, is a small space, the **pericardial cavity,** in which lies the **heart.** The heart is made up of the central muscular **ventricle** which is wrapped around the **intestine.** Note the two somewhat triangular **auricles** which are attached to the ventricle. If a live specimen is used and the heart is beating, count the number of contractions per minute.

Beneath the pericardial cavity are the dark-colored **excretory glands.**

Again note the position of the mouth. Probe through the mouth into the saccular **stomach,** near which is the brownish **digestive gland,** often called the liver. Now trace the intestine, beginning either with the place where it leads from the stomach or trace it anteriorly from the heart. The intestine can be readily traced posteriorly from the heart to the **anus.**

Complete and carefully index the prepared drawing on page 159, Fig. 97A (or 97B).

Other Mollusca. Examine other specimens of Mollusca displayed on the supply table.

PHYLUM ANNELIDA

Animals of this phylum are found in fresh water, in salt water, and on the land. An example is the common earthworm, *Lumbricus.*

423. How do these worms differ from the worms previously studied?

The earthworm. Lumbricus. Class Chaetopoda. On mild evenings, earthworms may be found by means of a flash light, particularly after a rain. If possible, observe and study some worms in their natural habitat.

424. How can earthworms disappear so quickly into their burrows?

425. Are they disturbed by jarring the ground?

426. Are they sensitive to light?

427. Why do they come out of their burrows at night instead of during the day?

Near the burrows may be found small piles of castings.

(*a*) Study a living earthworm placed on moist filter paper in a dissecting pan.

428. Does the animal have radial or bilateral symmetry?

429. How can you distinguish the anterior from the posterior end?

430. Can the animal move both forward and backward?

431. Is one end more sensitive than the other? How do you demonstrate this?

432. How often does the blood pulsate in the dorsal blood vessel?

(*b*) Procure a preserved specimen, place it in a dissecting pan, and study.

433. How many **somites** or **segments** are in the worm?

Notice the swollen region on the worm which practically conceals segmentation. This is the **clitellum.**

434. What is its function?

435. How many somites are swollen?

On the ventral side of the fifteenth somite note the two swollen areas, each with a central opening. These are the openings of the **vasa deferentia.**

436. What is the function of the vasa deferentia?

Study the ventral side of the animal. Stroke the ventral side gently with your finger and note that it is somewhat rough or "scratchy." This roughness is caused by the presence of small bristles called **setas.** Observe these small setas under a hand lens.

437. Describe the arrangement of the setas.

438. Are setas present on each segment of the earthworm?

439. What is the function of the setas?

(*Optional.*) Draw a ventral view of the first thirty-eight somites of the worm.

Carefully make a slit just through the dorsal body wall back of the clitellum. Then carefully cut through the dorsal body wall from the first incision to the anterior end of the animal. Do not cut deeply and be sure that the cut follows the dorsal surface. Sometimes it is helpful to pin the anterior end of the animal, dorsal side up, in a dissecting pan and direct the cut toward the pin. Now, with a dissecting needle, tear the **septa,** the segmental partitions which support the alimentary canal. Spread open the body wall and pin it to the wax in the dissecting pan. Now cover the animal with water.

ike all higher organisms, the earthworm is made up of an systems.

c) *Digestive system.* In the earthworm the digestive sys- begins with the **mouth,** which is located just under the per lip or **prostomium.** Leading from the mouth is a rt **buccal cavity,** which leads to the somewhat "fuzzy" rynx. Notice that this "fuzz" is the small **pharyngeal scles** which are attached to the body wall.

440. What is the function of these muscles?

Running posteriorly from the pharynx is the narrow ular **esophagus.** This leads into the enlarged **crop** which upies approximately two somites. Just back of the crop he **gizzard.** This leads into the **intestine** which opens at posterior end through the **anus.** Notice the relation of structures described to the septa or dissepiments. By ans of the septa and the outer "ring" markings, the undaries of the individual somites are easily distinguish- le.

Carefully check the somites in which these structures are und and sketch the organs in their proper positions in the epared outline on page 161, Fig. 98.

(*d*) *Reproductive system.* The large white-lobed bodies hich are found on each side of the esophagus are the minal **vesicles.**

441. How many are there?

442. What is the function of the seminal vesicles?

443. What is their relation to the vasa deferentia?

In addition to the seminal vesicles, two pairs of round obular **seminal receptacles** will be seen. These open ly externally.

444. What is their function?

The earthworm is a hermaphroditic animal.

445. What other reproductive organs should be present hich have not been mentioned?

Sketch lightly the organs of the reproductive system in heir proper position in your previous drawing (Fig. 98). Carefully check the somites where each organ is located.

(*e*) *Circulatory system.* Running along the middorsal egion of the intestine will be seen a dark line which may ppear broken in the preserved specimen. This is the **lorsal blood vessel;** it was the pulsations of this vessel in he living animal that you counted. Leading from this vessel, beginning in the region of the seventh somite, are the arge side branches, the **aortic arches** or **hearts.** These pass down around the esophagus to join the **ventral blood vessel.**

446. What is the function of the aortic arches?

Determine the number of aortic arches and the somites in which they are found. Sketch lightly the vessels of the cir- culatory system in their proper position in your previous drawing (Fig. 98).

(*f*) *Excretory system.* The excretory system is rather primitive. It consists of coiled tubes or **nephridia,** a pair of which is found in each somite, except the first three or four. These lie on either side of the alimentary tract. A nephridium appears to the eye as a fluffy mass lying between two adjacent septa. It has an internal opening into the coelom, called the **nephrostome,** and a minute external opening between the setas. Using forceps, remove a nephridium and mount it in water on a microscope slide. Examine it under the microscope. The funnel or nephrostome is very hard to find though you should have no trouble in seeing the coiled tube.

Draw several nephridia in their proper position in your previous sketch (Fig. 98).

(*g*) *Nervous system.* On the anterior dorsal surface of the pharynx will be seen two yellowish white bodies about the size of pin heads. These are the **cerebral ganglia,** sometimes called the **brain.**

Draw these structures in their proper position in your previous sketch (Fig. 98). After your lightly sketched drawing (Fig. 98) has been approved by an instructor, complete with hard pencil.

The cerebral ganglia are connected to a chain of connected ganglia called the **nerve cord,** which is ventral to the alimentary tract. These connections which pass around the pharynx are known as the **circum-pharyngeal connectives.**

Cut the stomach-intestine posterior to the gizzard and, holding it with the forceps, carefully dissect the alimentary tract from the body. Be careful not to cut the connectives with the cerebral ganglia. You should now see the **ventral nerve cord** with its swollen **ganglia.**

447. How many ganglia are there in a somite?

Remove a portion of the nerve cord and mount on a slide in some water. Observe with the low power of the microscope or with a hand lens.

448. Describe the arrangement of the nerves leaving the nerve cord.

If you desire, draw the complete nervous system. Do not insert in your previous sketch.

(*h*) *Cross section of the earthworm.* (*Optional.*) Examine a prepared microscopic section through the region of the intestine. This study has as its objectives a better conception of the relative position of the internal structures of the animal, and a study of structures (not observed in the invertebrates already studied) whose function is necessary for maintenance of the life of the earthworm. Use medium power of the microscope for this study.

The outer covering observed in the section is the noncellular **cuticle** which overlies the cellular **epidermis. Unicellular glands** are present in the epidermis.

449. What is the function of these glands?

Beneath the epidermis will be found a layer of **circular muscles** and under these the **longitudinal muscles** whose cut ends have a feathery appearance. Covering this layer, and lining the body cavity or **coelom,** is the thin **peritoneum.** In the center of the coelom will be found the **intestine**

which in cross section shows the dorsal wall folded in to form the **typhlosole.**

450. What is the advantage of this arrangement?

The cavity of the intestine is lined with an epithelium.

451. What type of epithelium is this?

The outer wall of the intestine is a modification of the peritoneal cells called **chloragen cells.**

Below the intestine will be found a cross section of the ventral **nerve cord.** The dorsal region of the cord shows three circles which are the cut ends of the **giant fibers.** The cut ends of the **lateral neural blood vessels** will be seen along the side of the cord. On the ventral surface of the nerve cord will be seen the **subneural blood vessel.** Note again the pear-shaped **motor nerve cells** in the nerve cord.

Locate the **dorsal blood vessel** and the **ventral blood vessel.**

452. Do you find any **setas** in your section? What is their relation to the muscle layers and coelom?

453. Do you find any portions of **nephridia?** If so, why do they appear in the sections as they do?

454. Why are sections of the reproductive system missing?

455. How does the earthworm move?

Indicate on the sketch of the internal anatomy (Fig. 98) where this section might have been taken.

Complete and fully index the prepared drawing of the cross section of the earthworm on page 163, Fig. 99.

Examine other specimens of Annelida furnished by the instructor, and compare these with the earthworm just studied.

PHYLUM ARTHROPODA

Examine an insect, a crayfish, a centipede, and a spider.

456. What common characteristics do these animals have?

457. How many pairs of legs are there on an insect?

458. How many pairs of legs has a crayfish?

459. How many pairs of legs has a centipede?

460. How many pairs of legs has a spider?

An exoskeleton of chitin covers the body.

461. Is this true of all the animals mentioned above?

462. What structures of the mollusks are analogous to this?

463. Into how many subgroups or classes would you divide the animals studied above?

The crayfish. Class Crustacea. These are arthropods that breathe by means of gills, and have one pair of antennas and one pair of branched antennules. This class includes such animals as crayfish, lobsters, crabs, sow-bugs, and shrimps.

Crayfish are found in brooks, creeks, swamps, and in other bodies of fresh water. When disturbed, they usually hide under rocks and debris. If it is impossible to [illegible] crayfish in their natural habitat, study the live [illegible] the aquarium.

464. When under rocks what is the position of the [illegible] with regard to the entrance?

465. Are the **antennas** moved frequently?

466. Of what advantage are **stalked eyes?**

467. Describe the locomotion of the crayfish.

Try feeding a crayfish.

468. Describe the method of securing food.

The crayfish breathes by means of **gills** which are located under the **carapace.** With a medicine dropper place some India ink under the border of the carapace.

469. Record your observations.

(*a*) *External anatomy.* The fusion of the head and thorax forms the **cephalo-thorax,** the dorsal covering of which is called the **carapace.** The head region of the crayfish is marked off from the thorax by the **cervical groove.** Note the anterior prolongation of the carapace into a sharp point called the **rostrum.** Examine the free edge of the carapace. Underneath the lateral plates is the **gill chamber.**

470. Of what advantage is it that the carapace is not attached ventrally?

471. What is the function of the hairy spines along its ventral border?

The **abdomen** shows evidence of segmentation. Each segment bears a pair of jointed **appendages.** The last segment, which may be mistaken for a "tail," is known as the **telson.** Note that each segment is made up of a dorsal **tergum,** two lateral **pleura** (singular, pleuron), and a ventral **sternum.**

472. How are the abdominal segments arranged to allow flexibility?

If you so desire, draw the structures just mentioned.

(*b*) *The appendages.* (*Optional.*) The appendages of Arthropoda are interesting organs because they are good examples of homology and show the adaptation of a generalized primitive type of structure for various functions. Here, just as we observed in the study of the limbs of vertebrates, there is a generalized appendage from which the different modifications or variations may be derived. This generalized type in the Arthropoda is known as a **biramous** (two-branched) **appendage,** and it is exemplified by the appendages on the abdomen which are known as **pleopods** or **swimmerets.**

Study the fifth pair of pleopods. Each pleopod is made up of the basal attaching piece called the **protopod.** Attached to the protopod are an inner or median branch, the **endopod,** and an outer or external branch, the **exopod.** The last pair of pleopods, that is the pair next to the telson, are modified as swimming organs and are known as the **uropods.** The first two pairs of pleopods are variously modified according to the sex of the animal, those of the male being modified to form copulatory organs.

Observe several preserved crayfish and describe
dification of the pleopods found in each sex.
erior to the pleopods and attached to the thorax are
irs of walking legs or **pereiopods.** Each pereiopod of
st pair is modified at the free end to form two large
or pincers called the **chelas.** These are used in
ıg and crushing.
How does the second pereipod differ from the third
d?
How does the first pereiopod differ from the other
ereiopods?
Do you find any ball-and-socket joints present?
n a chela with your scalpel and study the muscle ar-
nent for opening and closing.
. What is the advantage of such an arrangement?
ated in front of the first pereiopods are the **third**
ipeds. There are three pairs of maxillipeds, two pairs
xillas, and one pair of **mandibles.** These make up the
ı appendages. Remove in order from the right side,
ird, second, and first maxillipeds, also the second and
naxillas. Now compare each of these appendages with
fth pleopod and with each other. Note the broad
e, the **scaphognathite,** on the second maxilla. The
libles are not true appendages.
aw the appendages dissected if you so desire. Con-
t a chart somewhat similar to the one used for compar-
of the various vertebrate limbs to the typical penta-
l limb. This chart should record changes in structure,
he function of each of the various appendages.
ıe **antennas** are the only remaining appendages which
onsidered to be biramous.
8. What is the function of the antennas?
9. What is the function of the antennules?
lls. Remove the gill cover from the right side and
y the **gills.**
0. How are the gills arranged and attached? (There
hree types of attachment.)
1. How does the water get into and leave the gill
nber? Recall previous experiment with the India ink.
2. Describe one of the gills.

) *Digestive system.* Beginning at the posterior margin
ıe carapace, with the scissors make two incisions parallel
he median line and extending anteriorly to the base of
rostrum. Then remove the section of the carapace. On
oval of the hard carapace, a thin membranous covering,
pigmented membrane, will be seen.
3. What is the function of the pigmented membrane?
arefully remove the pigmented membrane. The chitin-
stomach will be seen medially and anteriorly. Note
short **esophagus** leading from the **mouth** to the stomach.
stomach has a well-defined anterior **cardiac region** and a
erior **pyloric region** to which are attached two groups of
cles. These are the **anterior** and **posterior stomach**
cles. Lateral to the stomach are two somewhat oval-
shaped muscle masses, the **mandibular muscles.** Near these muscles are the anterior ends of the yellowish-green **digestive glands,** commonly known as the liver. Back of the stomach is a somewhat hexagonal, white structure, the **heart.** The heart should be carefully removed, placed in a watch glass containing some water, and kept for future study.

(*d*) *Reproductive system.* Under the anterior region of the heart note the **gonads.** In the male the **testis** is a slender white coiled tube, and in the female the **ovary** may be somewhat yellow in color. Eggs may be present. Trace the tubes leading from the gonads.

484. What is the name of these ducts?

485. Where do the ducts open to the exterior?

Remove the dorsal wall of the abdomen by making two lateral parallel cuts with the scissors, thus practically cutting off the tergum of each somite. Carefully remove the muscles and identify the posterior portions of the lobes of the digestive glands, and the intestine. In the sixth abdominal segment the intestine enlarges and forms the **rectum.**

(*e*) *Circulatory system.* Study the heart. Note its peculiar shape. Examine it with a hand lens, or with the lowest power of the microscope, and note the small openings or **ostia** leading into it. Study an injected lobster and note a median **ophthalmic artery** which passes anteriorly to the rostrum and two **antennary arteries** which lead off toward the mandibular muscles. Note the two small **hepatic arteries** which leave the heart below the antennary arteries and disappear in the liver and gonads. Study the model of the crayfish, noting the great **sternal artery** extending downward, and the small dorsal **abdominal artery** running posteriorly above the intestine.

(*f*) *Excretory system.* This consists of two oval organs called **green glands** located near the antennary muscles. These glands have the same function as kidneys.

(*g*) *Nervous system.* Remove the thoracic viscera, the intestine, and the muscles of the abdomen to expose the ventral nerve chain or **nerve cord.** Note the position of the **ganglia.**

486. How are the ganglia arranged with respect to the somites?

Trace the nerve cord forward. In the thorax it passes beneath some chitinous plates and lies in the **ventral blood sinus.** Under the esophagus is the much enlarged **subesophageal ganglion** from which two connectives pass. These **circumesophageal connectives** extend around the esophagus and join the ventral nerve cord to the dorsal **cerebral ganglion** or **brain.**

487. What evidence is there that the thorax and head may be made up of a number of fused segments?

Carefully complete and index the drawing of the crayfish on page 165, Fig. 100.

A centipede or a millipede. Class Myriapoda. (*Optional.*) These are arthropods with tracheae, one pair of antennas, and many similar legs.

488. Is the body segmented?

489. What body regions are present?

Note that in the centipedes and millipedes all the segments are movable except a small number near the head.

Sketch and classify a myriapod. Without assistance from the instructor, identify, draw, and index six structures.

A spider. Class Arachnida. (*Optional.*) In this class the **cephalo-thorax** is a group of fused segments. Note that the **abdomen** is also a group of fused segments. Identify these regions.

Without assistance from the instructor, sketch and classify an arachnid. Identify, draw, and index eight structures.

Insects. Class Insecta. These are arthropods with tracheae, one pair of antennas, and three pairs of legs. In insects a number of segments are fused to form a **head,** others are fused to form a **thorax,** whereas the segments of the **abdomen** remain more or less movable upon one another.

Animals of one class yet differing from one another in certain characteristics are grouped in divisions called orders. Class Insecta has been divided into nineteen or more different orders. Representative insects from the most common of these orders will be studied.

The grasshopper. Order Orthoptera. These are insects with four wings. The **fore-wings** are hard and leathery, but the **hind-wings** are more delicate and folded like a fan. Metamorphosis is incomplete. This order includes grasshoppers, crickets, roaches, and certain other insects.

The grasshopper is a representative insect. Note that the body is divided into three well-defined regions, the **head, thorax,** and **abdomen.**

490. Is the head movable?

Note the two large **compound eyes.** In addition to the compound eyes there are three **simple eyes** called **ocelli** (singular, **ocellus**). One of these is located in the center of the head and one at the base of each antenna. Note the segments of the antennas.

491. Are the antennas rigid or flexible? What is the advantage of this feature?

The thorax is the body region back of the head. It is divided into three main regions which may be roughly distinguished since each bears a pair of legs. Beginning with the most anterior, these are the **prothorax,** the **mesothorax,** and the **metathorax.**

Each leg is made up of five divisions, which are, beginning with the division nearest the body, the **coxa, trochanter** (these two segments are fused in the large leaping legs), **femur, tibia,** and **pulvillus.**

There are two pairs of wings which differ greatly in form and texture. The outer wings are long, narrow, and parchment-like. These are the **mesothoracic wings** or tegmina. The second pair of wings, the **metathoracic wings,** are more delicate texture and, when not in use, are folded somewhat like a fan.

492. How does a grasshopper hold its wings in flying?

493. The abdomen is made up of how many segments?

Underneath the wings, on the first abdominal segment, is a large opening covered by a membrane. This is the "ear," the **auditory organ.** The membrane is called the tympanum. Each segment of the abdomen is made up of a dorsal tergum, a lateral **pleuron,** and a ventral **sternum.** The posterior end of the abdomen of the male differs from that of the female. In the female the most prominent part of the caudal portion of the abdomen is the **ovipositor.** Note, along the sides of the abdomen, small openings (the **spiracles**) by means of which air is taken into the body. Locate these spiracles.

On page 167, Fig. 101, complete the drawing of the side view of the grasshopper, showing the above points.

(*a*) *The mouth parts.* The mouth parts of insects are of particular interest since these are important as a basis of classification and they serve as an index of the food habits of the animal.

494. Upon what do grasshoppers feed?

Covering the ventral, anterior part of the head is a movable flap, the upper lip or **labrum.** Remove it with the scissors and place in a watch glass. Beneath the labrum will be seen the hard, dark-colored **mandibles** which are toothed along the biting surface. Remove one of the mandibles and place it with the labrum. Beneath the mandibles will be found the paired **maxillas.** Notice the **maxillary palp** along the outer side. With your scissors remove one of the maxillas and place it in the watch glass in as nearly as possible its relative position. Remove the remaining appendage, the **labium,** which forms a sort of lower lip, and place it with the other mouth parts. Note that the labium is cleft along the middle line and bears a pair of **labial palps.**

Draw each of these appendages (X2) on page 167, Fig. 102. Arrange your figures to show as nearly as possible the relative position of the parts in the animal.

(*b*) *Internal anatomy of the grasshopper.* (*Optional.*) Remove the wings and then cut away the dorsal portion of the wall of the abdomen and thorax. The **heart** is removed with this portion of the body wall; consequently you will probably not be able to determine the nature of its structure. Note the absence of mesenteries and a well-defined coelom. With a hand lens, study the **tracheal tubes** as they leave the spiracles. Mount a piece of a trachea on a slide and study it under the microscope.

495. Describe a tracheal tube.

The sex of the animal can be determined by noting the presence or absence of the ovipositor. Note the gonads lying near the dorsal surface of the posterior region of the abdomen. If the specimen is a male, identify the vas

ıtia. If the specimen is a female, identify the s.

Are there any eggs present?

two oviducts unite into a common tube which leads exterior.

On the basis of knowledge already acquired, suggest me of this tube.

e this tube to its external opening between the plates ovipositor.

ıove the gonads. Note the **esophagus** which arches d from the mouth into the thoracic cavity where it into the **large crop.** Posterior to the crop is the ted **stomach** or **ventriculus.** Partically covering the ch and attached by their median regions are a number ıdle-shaped sacs, the **gastric caeca.**

. What is the probable function of these caeca?

stomach extends some distance behind the gastric where it joins the **intestine.** The region of junction is ed by a slight constriction and hardening of the wall alimentary canal. Covering this junction is a mass of d threads, the **uriniferous** or **Malpighian tubules.**

. Can you suggest the function of these tubules?

ore posteriorly, the intestine narrows to form the **colon** nd **intestine.** Posterior to the colon the alimentary enlarges to form the **rectum** which opens to the exterior gh the **anus.**

the prepared outline on page 169, Fig. 103, sketch y the structures thus far observed.

t through the rectum and lift up the alimentary canal, exposing the **ventral nerve cord.** Trace this cord iorly.

0. How many pairs of **abdominal ganglia** are present?

ote that in the thoracic region the nerve cord disappears r an ingrowth of the exoskeleton. Remove this cover- nd expose the thoracic region of the nerve cord.

1. How many thoracic ganglia are there?

race the nerve cord farther forward and find the two ımesophageal **connectives** which join the ventral nerve to the **cerebral ganglia** or **brain.**

2. What animals previously studied have a nervous em somewhat similar to that of the grasshopper?

n page 169, Fig. 104, draw the nervous system just ob- ed.

ther orders of insects. Examine the representatives of following three orders of insects furnished by the ructor.

rder Lepidoptera. These are insects with four mem- ous wings covered with scales. They usually have ing mouth parts. The antennas are knobbed or feath- Metamorphosis is complete.

3. What insects belong to this order?

rder Coleoptera. These are insects with four wings. fore wings are sheath-like and cover the membranous wings. They have biting mouth parts, and metamorphosis is complete. Identify several insects belonging to this order.

Order Hymenoptera. These are insects possessing four membranous wings with few veins. The first abdominal segment is fused or partly fused with the thorax. The mouth parts are adapted for both chewing and sucking. Metamorphosis is complete. Identify several insects belonging to this order.

Order Diptera. Flies and Mosquitoes. This is a very large order of insects including certain species which are very important as vectors of diseases. Examine the specimens furnished you.

504. What anatomical differentiations are peculiar to this order?

(*a*) *Mouth parts of the horse fly.* Recall the mouth parts of the grasshopper. With the anatomy of these structures in mind, study the mouth parts of the horse fly. Identify the large **maxillary palps.** Lying along the dorsal surface of the large labial trunk note six long, slender-pointed **stylets.** The uppermost unpaired, flat, blunt-tipped piece is the **labrum.** The first pair of stylets underneath the labrum is the flat, smooth sharply pointed **mandibles.** Underneath the mandibles are the somewhat softer and narrower **maxillas** whose palps you have already identified. The sixth unpaired stylet is the **hypopharynx,** an unpaired slender structure lying below the maxillas. Beneath the group of stylets just seen, is the long proboscis-like **labium,** on whose upper surface is a shallow groove in which the stylets may be partially enclosed. At the free end will be seen an expanded, disk-like structure, the **labella,** which may represent greatly modified **labial palps.**

On page 169, Fig. 105, draw the mouth parts just studied.

(*b*) *The house fly.* Study the external anatomy of the house fly as seen under a hand lens.

505. Compare the external anatomy of the house fly, exclusive of mouth parts, with the grasshopper.

506. How would you consider the house fly adapted externally for spreading disease?

Study the mouth parts of the house fly. Note that the **mandibular** and **maxillary stylets** are missing. The **labium** is present with the **labrum-epipharynx** almost fused with its dorsal surface. **Maxillary palps** are present and are made up of one segment only. The mouth parts of the house fly, you will note, are much fused and modified to form a sucking proboscis.

(*c*) *The mosquito.* Study the external anatomy of the mosquito.

507. What resemblances do you note between the mosquito and the flies just studied?

You have already studied the mouth parts of two members of Order Diptera. Now make a study of the mouth parts of the mosquito and try to identify the various structures already seen in the grasshopper and the flies studied.

508. Are the mouth parts of the mosquito adapted for chewing; or for sucking; or for piercing and sucking?

Study the larva of the mosquito.

509. Where do the larvae live?

510. How do they get oxygen?

511. What measures may be taken to control the mosquito?

512. List six diseases transmitted by dipterans, the specific insect acting as vector, and the geographical region where the disease is most prevalent.

Order Siphonaptera. Fleas. (*a*) Study the external anatomy of a flea. Remember that fleas live among the hairs or feathers of their hosts.

513. How would the shape of the body adapt this parasite to its mode of life?

514. Do you find any structure on the flea which would assist it to live on the host?

515. Are there any wings present?

Study the legs of fleas and compare them to those of the grasshopper.

516. What is the method of locomotion of the flea?

Study the mouth parts of the flea.

517. Would you say they are adapted for chewing; for sucking; or for piercing and sucking?

518. Name four diseases transmitted by fleas.

PHYLUM ECHINODERMATA

The animals of this phylum are all marine. Examine the specimens provided.

519. What type of symmetry do these animals have?

520. How can you prove this?

521. What is the general external appearance of these animals?

Note that these animals all have fleshy protuberances, the **tube feet,** which are used in locomotion.

The starfish. Class Asteroidea. (*Optional.*) If the laboratory is equipped with a salt-water aquarium containing live starfish, make the following observations.

522. How does the animal "walk"?

523. How does it feed?

524. Turn the animal "on its back" and describe the method by which it rights itself.

Examine the preserved specimen furnished, and observe that the animal is made up of a central region or **disk,** leading from which will be found the **arms.**

525. What type of symmetry has the starfish?

The oral surface differs from the aboral surface in that on the oral surface will be found the **mouth** in the center of the disk leading from which are grooves to each arm, the **ambulacral grooves.** On the aboral surface, note the small **circular madreporic plate.** Water enters through this plate to a complex system known as the **water vascular system.** Adjoining the plate are two arms, the **bivium.** The remaining three arms are known as the **trivium.**

526. Examine the madreporic plate with a hand lens and describe its structure.

527. How is the animal protected?

Study once more the oral surface and note that the ambulacral grooves are filled with a number of small "suction cup like" structures, the **tube feet.** Notice the **spines** along the edge of the grooves.

528. How do these differ from the other spines found on the animal?

Scrape the tube feet from a dried specimen and, by studying the **pores** through which the tube feet extend, determine whether or not they have a definite arrangement.

Draw, if you desire, the oral and aboral views of the starfish. If a dried specimen of suitable size is available, place this on your drawing plate and trace around it to furnish the outline for the drawing.

On the surface of the starfish in various regions are small microscopic pincer-like structures known as **pedicellariae.** Remove some of these by scraping around a spine with the point of a scalpel. Mount in some water on a slide and examine under the microscope.

529. Describe the structure of a pedicellaria.

(*a*) *Internal anatomy of the starfish.* With scissors cut off the tips of two of the arms of the trivium. Cut along the side of each of the arms into the disk. Lift the aboral surface of the arm at its tip and carefully cut away the **mesenteries** which attach the organs to it. After these cuts have been extended to the disk, remove the aboral surface of the disk, taking care not to cut too deeply or to injure the madreporic plate. Place the specimen in a dish and cover with water. In each arm there is a pair of long leaf-like organs called **hepatic caeca.** These are the digestive glands. The ducts of each pair unite to form a common duct which leads into the **pyloric sac,** a division of the **stomach.**

530. How many pairs of these glands are found in the starfish?

Note carefully the shape of the pyloric division of the stomach which rests upon the larger and more oral **cardiac division.** Attached to the cardiac stomach will be found **retractor muscles** which are attached to the **ambulacral ridge** found on each arm. Note the mouth and see into what division of the stomach it opens. On the pyloric stomach may be found a **short rectum** and the much-lobed **rectal caeca.**

531. Describe the relation between the stomach arrangement and the feeding habits of the starfish.

Where each arm leaves the disk there may be found the **gonads** of the animal. These resemble microscopic bunches of grapes. Both the male and female gonads resemble each other so closely that it is almost impossible to determine the sex of the animal.

) *The water vascular system.* Leading from the madre-te will be found a small hardened tube, the **stone canal,** h leads to a **circular canal** surrounding the mouth. m the circular canal a **radial canal** leads out to each arm. se canals or radial water tubes are found along the oral ace of the ambulacral plates, in a sense, outside the nal. Along the sides of the ambulacral ridge previously ntioned are the rows of the small saccular **ampullas.**

32. What is the relation of the ampullas to the ambula- pores and the tube feet?

The ampullas and the tube feet are joined to the radial al by **connecting tubes.** These details just mentioned best be seen either in injected specimens or in the study he cross section of the arm of the animal.

33. Explain how the tube feet provide locomotion for animal.

On page 171, Fig. 106, complete the drawing of the dis-ted animal to show the structures to which your attention s already been called.

Other members of the Echinodermata. Study and classify ner species of Echinodermata provided by the instructor.

534. In what respects do these forms resemble the starfish lass Asteroidea)?

PHYLUM CHORDATA

Most of the animals belonging to this phylum have a sup-orting backbone composed of vertebras. Examine the eleton of a bird, a cat, a frog, a fish, and a snake or lizard. wo pairs of typical jointed appendages are usually present all vertebrates.

535. How are these appendages modified?

536. How does this supporting framework differ from that ound in previous phyla?

Class Chondrichthyes and Class Osteichthyes. (Formerly ncluded in Class Pisces.) Examine the specimens furnished y the instructor. These are cold-blooded aquatic animals hat breathe by **gills.** The body is somewhat spindle-shaped nd is provided with **dorsal fins, tail fin, ventral fin, pectoral ns,** and **pelvic fins.** Verify in a specimen. Observe that **cales** usually cover the body. The gills are usually covered y a flap, the **operculum.**

Class Amphibia. Examine the specimens furnished by the nstructor. These animals are cold-blooded and live part of he time on the land and part of the time in the water. There are usually two pairs of limbs with five digits each. Examine a toad, a frog, and a salamander.

537. Are there any scales present?

538. Are there any claws on the digits?

The skin is made slimy by a mucous secretion. The oung breathe by means of gills and the adults usually have ngs.

(*a*) *Order Caudata.* These are the salamanders, newts and water dogs. These animals have tails, and external gills are sometimes present throughout life. Gills are often miss-ing in the adult stage. Examine a number of the represen-tatives of this order.

(*b*) *Order Salientia.* These are tailless amphibians such as frogs and toads. External gills are absent in the adult, and breathing is carried on by means of lungs and skin.

Class Reptilia. Examine the specimens furnished by the instructor. Belonging to this class are the lizards, snakes, turtles, and alligators. They are cold-blooded animals. Breathing is carried on by means of lungs.

539. How does the covering of the skin differ from that of the amphibians?

540. Compare the digits of the reptiles with those of the amphibians.

(*a*) *Order Chelonia.* This order includes turtles, tortoises, and terrapins. The body is usually enclosed in a bony shield-like structure overlaid in many cases with thin, plate-like scales. In the cleaned specimen note how the girdles and appendages are arranged.

541. Are there any teeth present?

(*b*) *Order Crocodilia.* This order includes the alligators and crocodiles. The bodies are covered with hard, coarse scales.

(*c*) *Order Squamata.* This order includes the snakes, lizards, and chameleons.

Class Aves. These are warm-blooded animals.

542. What is meant by a warm-blooded animal?

543. What adaptations do you find for the maintenance of body temperature?

Examine a feather. Note the stiff axial rod or **rachis.** The side of the feather, made up of a series of parallel threads, **barbs,** is called the **vane.** Examine under the microscope and note that each barb bears a fringe of small processes, the **barbules,** along either side. The bird is covered with three kinds of feathers: the **contour feathers,** similar to the one just described; the **down feathers,** which possess a soft shaft and a vane without barbs; and the **filoplumes,** possessing a slender hair-like shaft and few or no barbs.

On page 173, Fig. 107, sketch a portion of a contour feather as seen under the microscope.

Examine the birds furnished by the instructor.

544. State in a sentence the mode of life and habitat of each bird. List, under each sentence, the structural modifi-cations of beak and foot, or any other observed modifications that fit the bird for its peculiar mode of life.

545. How are the fore limbs modified?

546. How are the feathers of the fore limbs differentiated from the others? Is there any advantage in this?

Examine the skull of a bird.

547. Do you find any teeth present?

548. How many occipital condyles do you find on the skull?

549. What class of chordates do the birds most closely resemble? Give reasons for your answer.

Class Mammalia. To this class belong man, monkeys, whales, bats, seals, cats, dogs, and many common wild and domestic animals. These animals are **warm-blooded.** The skin is usually covered with **hair.**

550. Can you name any modifications of this covering?

551. How does man maintain a constant body temperature?

The young are nourished after birth by secretions from the mammary glands of the mother.

A further study of systematic or taxonomic work in biology shows new divisions. Orders are made up of smaller groups called families. The members of these groups have characteristics less fundamental than those of orders. Families are further divided into genera, and the genera are in turn broken up into species. Specific characters tend to be more superficial, such as colors, form of the body, and distinctive markings. (These characteristics are fairly constant in any given species, but they may vary widely in the different species of a genus.) For the identification of these various species, there have been compiled "keys" which are simplified tabulations of characters.

552. Which groups are most closely related, phylum or order? Phylum or class?

THE PLANT KINGDOM. TAXONOMY

Just as all known animals have been arranged according to their supposed relationship into various divisions, so have all known plants been arranged. Each group of plants is composed of members all having some characteristics in common, as will be seen from the study of the following exercises.

PHYLUM THALLOPHYTA

This large phylum is subdivided into several divisions, of which the two most important are the **Algae** and **Fungi.**

Algae. These are the simplest of green plants, inhabiting fresh-water streams, lakes, and ponds, as well as moist soil, wet banks, and the bark of trees. Some forms live in the oceans and seas. The fresh-water algae often occur in simple colonies in which the cells are arranged to form chains, nets, or spherical aggregates. Here also occur some of the simplest representatives of the multicellular plants.

Blue-green algae. Class Myxophyceae. The blue-green algae are the simplest plants possessing chlorophyll.

(*a*) *Gloeocapsa.* Mount some specimens of *Gloeocapsa* in water and examine under the microscope.

553. Are these unicellular or multicellular plants?

554. Describe the cell wall.

555. Can you see a nucleus?

556. How do these plants reproduce?

Sketch on page 175, Fig. 108.

(*b*) *Nostoc.* Examine some *Nostoc.* Note the occasional large apparently empty cells (**heterocysts**).

557. Is this a unicellular plant, a multicellular plant, or a colony? Give reasons for your answer.

Sketch on page 175, Fig. 109.

(*c*) *Oscillatoria.* (*Optional.*) Mount some *Oscillatoria* in water and study under the microscope. Observe the **filaments** carefully.

558. Describe the movement of the filaments.

559. Is *Oscillatoria* a multicellular plant or a colony?

Green algae. Class Chlorophyceae. The green algae are the commonest and most widely distributed of all the algae.

(*a*) *Pleurococcus.* This plant occurs in the form of single cells or loose colonies growing on bark and moist surfaces of all kinds, such as boards, stones, and brick walls.

560. Does the green incrustation have a definite form or structure comparable to that of the higher green plants?

561. Make a list of the processes necessary to the life of higher plants carried on by this one-celled plant.

Scrape off a little of the green incrustation and mount in a drop of water on a glass slide. Be careful not to remove pieces of bark or dirt with the plants. Examine with the low power of the microscope.

562. Describe the appearance of the green masses observed under the low power.

Now observe with the high power.

563. Is the plant unicellular, multicellular, or colonial?

The green central part of a cell is the **chloroplast.** Note the thick **cell wall.**

On page 175, Fig. 110, sketch two or three green masses to show their structure. Index and classify.

564. Is the reproduction of *Pleurococcus* sexual or asexual?

Look for *Pleurococcus* on the bark of trees and bring a small collection of the green incrustation to class the next period.

(*b*) *Scenedesmus.* (*Optional.*) Make a drawing under high power of a colony of *Scenedesmus.*

565. How does it differ from *Pleurococcus?*

(*c*) *Oedogonium.* Observe a filament of *Oedogonium* under the low power of the microscope.

566. Is this a multicellular plant or a colony?

Study under the high power and look for the **pyrenoids** and **nuclei** of the **vegetative cells.** The pyrenoids are small bodies of reserve food material embedded in the **chloroplast.** Try to find a cell containing **zoospores.** Locate an enlarged

ded cell, an **oogonium,** containing an **egg.** Identify **antheridia,** much-shortened cells, each containing two **ms.** After fertilization, a thick wall is formed about the **te.** Try to locate a zygote.

n page 175, Fig. 111, make a sketch to show all these ures, and diagram the life cycle of *Oedogonium.*

l) *Vaucheria.* Examine a filament of *Vaucheria.*

67. Do you observe any cross walls?

68. What name is given to such a structure?

ocate the short branches bearing the oval swollen **onia** and the slender curved **antheridia.**

Make a sketch on page 177, Fig. 112, to show these struc-es.

e) *Spirogyra.* Mount some of the green mass on a slide study under low power of the microscope. Later change high power.

69. Is the green mass composed of one plant or many?

Note the spiral band-like structures, the **chloroplasts.** mplete the sketch of a filament of *Spirogyra* on page 177, . 113. Be sure to include all structures. Index carefully.

Study, from prepared slides, conjugating plants, using power. Observe the method of union of the filaments.

570. Do you find different stages in the formation of pro-sions from the cells and in the formation of connecting bes?

Observe in some cells the rounding up and collection of e cell material to form **gametes.**

571. Do you find any gametes passing from one filament the other?

572. Do you find any **zygospores** (zygotes)?

Draw two or three stages in fertilization as observed and clude in Fig. 112.

(*f*) *Chara or Nitella, the stoneworts.* (*Optional.*) Ex-nine these plants growing in an aquarium. Observe the anches borne in whorls at the **nodes** and separated by the ongated **internodes.** Using a hand lens, locate the **ntheridia,** spherical, orange-colored bodies borne on the ort branches. Also locate the **oogonia.** These are darker, ask-shaped bodies borne on the short branches.

Make a sketch on page 179, Fig. 114, showing these ructures.

(*g*) *Diatoms.* Examine under high power a slide on which re two or three different forms of diatoms. Note the **valves,** ne markings, and the **chloroplast.**

Sketch on page 179, Fig. 115, to show these features.

573. Of what economic importance are diatoms?

Brown algae. Class Phaeophyceae. The brown algae are mostly marine, being widely distributed along the rocky hores of oceans in the temperate zone.

(*a*) *Fucus, a rockweed.* Study the general habits of *Fucus,* marine brown alga. A plant body of this type is known as a **thallus.** Observe the little swellings on the thallus. These are the **bladders.**

574. What is the function of the bladders?

575. How is *Fucus* adapted to withstand drying while exposed at low tide?

Note the swollen tips of the branches. These are the **receptacles.** The little spots on the receptacles mark the position of internal chambers (**conceptacles**) in which the sex organs (**antheridia** and **oogonia**) are produced.

Complete the drawing of *Fucus* on page 181, Fig. 116.

Study a cross section of a receptacle under the low power of the microscope. Note the position of the **conceptacles.** Now study the section under the high power. Observe the sterile filaments or **paraphyses** and the sex organs.

576. Do these conceptacles contain oogonia, antheridia, or both?

577. How many **eggs** are formed in a single **oogonium?**

Locate an **antheridium** containing **sperms.**

Carefully label the drawing of the conceptacles on page 181, Fig. 117.

(*b*) *Kelps.* Examine and sketch a specimen of *Laminaria.*

578. Of what economic importance are kelps?

579. Where do they grow?

Red algae. Class Rhodophyceae. A few species of red algae occur in fresh water, but the great majority of these plants are confined to marine habitats, being most abundant in the warmer ocean waters. Examine the various kinds of red algae supplied by the instructor.

Nemalion. (*Optional.*) (*Batrachospermum* may be studied instead of *Nemalion.*) Study the plant as it appears to the naked eye. Now place a portion of the plant body in water on a slide and crush beneath the cover glass. Examine under the high power.

580. Are the cells of the thallus of uniform size and shape?

581. How are the cells held together?

Make a sketch on page 183, Fig. 118, of a part of a filament. In a prepared slide (provided), locate the sex organs. Find a cluster of **antheridia.** Each antheridium produces one non-motile male **gamete** (**spermatium**) which is released at maturity. Locate a female sex organ, the **carpogonium.** The long thread-like extension is the **trichogyne.**

582. What is the function of the trichogyne?

When the zygote develops it gives rise to numerous short filaments. At the end of each filament a **carpospore** is formed. This entire fruiting body is called a **cystocarp.** The non-motile carpospores are finally released and each one is capable of developing into a new plant.

Make sketches on page 183, Fig. 119, of the antheridia, carpogonium, and cystocarp. Diagram the life cycle of *Nemalion.*

The fungi. The fungi differ from most plants in that they lack chlorophyll. They are, therefore, dependent plants, living either as saprophytes or parasites. The food supply

on which the fungus grows is called the substratum or medium.

Bacteria. Class Schizomycetes. (*a*) Mount a drop of stagnant water containing decaying organic material on a slide. Study with high power and describe what you see. Identify **bacilli, spirilla,** and **cocci forms.**

On page 185, Fig. 120, draw the forms found.

Observe the various types of bacteria you can find on the prepared slide furnished.

583. Describe the appearance of each.

(*b*) (*Demonstration.*) Expose Petri dishes containing sterile agar nutrient to the following conditions:

To the air of the laboratory for one-half hour.

To the outside air for one-half hour.

To dirt or scrapings from the hands. Cover immediately.

To contact with two or three hairs from the head. Cover immediately.

After one-half hour cover the remaining dishes and place on the table in the laboratory. After three to five days note the conditions of the various plate cultures. Count the number of spots of bacteria and molds growing on the culture medium.

Summarize the results in the table on page 185, Fig. 121.

584. Where are bacteria found in greatest abundance?

585. What fundamental laws of health and hygiene might be derived from this experiment?

586. What do we mean when we say we "preserve" some fruit?

(*c*) *Nodule bacteria.* Remove and wash carefully the roots of a clover plant. Note the **tubercles.**

587. What does each tubercle contain?

588. What process takes place in connection with the tubercles?

589. Of what importance is this process in the cycle of nature?

590. Explain the importance of nodule bacteria.

Slime molds. Class Myxomycetes. Examine the material provided by the instructor.

591. Why are these organisms claimed by both botanists and zoologists?

Class Phycomycetes. Many of our common and destructive fungi are included in this group.

(*a*) *Bread mold* (*Rhizopus*). (*Saprolegnia* is a more representative phycomycete than *Rhizopus*, and the optional study of *Saprolegnia* may be substituted for the study of *Rhizopus*.) *Rhizopus* is commonly found growing on bread. Note that the bread is covered with a great number of white filaments or **hyphae,** which, taken collectively, form the **mycelium.** This mycelial growth is found in most of the fungi.

592. Do the hyphae have cross walls?

593. What name is applied to a plant having this structure? What alga has the same structure?

594. What is the function of the hyphae?

Observe that some portions of the mycelium are covered with round black balls, the mature **sporangia.** Mount a patch of this mycelium on a slide and study under the high power of the microscope.

595. Describe the appearance of the sporangia.

Note that the sporangia contain little black bodies, the **spores.** The stalks which bear the sporangia are called the **sporangiophores.** The enlarged upper end surrounded by the spores is the **columella.**

596. Is this plant independent or dependent?

597. To what group of the fungi does this fungus belong? Why?

On page 187, Fig. 122, sketch a portion of the mycelium to show the features observed above.

(*b*) (*Optional.*) In prepared slides or specially selected material identify the **suspensors, gametes,** and **zygotes** involved in the sexual reproduction of *Rhizopus.*

(*c*) *Water Mold* (*Saprolegnia*). Examine some of the **mycelium** under the microscope.

598. Do the **hyphae** have cross walls?

Attempt to find a hypha in which the swollen end is cut off by a cross wall. This is a **sporangium.** Find a sporangium containing **zoospores.**

599. How do these spores differ from those of bread mold?

Look for spherical bodies, the **oogonia.** Try to find the small **antheridial filaments** lying on the surface of the oogonium.

On page 187, Fig. 123, make sketches to show the structures mentioned.

Class Ascomycetes. This is by far the largest group of fungi, including a great variety of forms, many of which cause serious diseases of cultivated plants.

(*a*) *Peziza.* Examine the fruiting body (**apothecium**) of *Peziza.*

600. What is the shape of this body?

Observe the lining of the cup, the **hymenium.** Remove a very small portion of the hymenium and place in water on a slide. Tease thoroughly or crush beneath the cover glass. Examine under low and high power. Observe the sac-like **hyphae** containing the **spores.** These hyphae are called **asci** (singular, **ascus**).

601. How many spores are there in an ascus?

602. What are these spores called?

Between the asci are more slender, sterile hyphae called **paraphyses.**

On page 187, Fig. 124, sketch a small portion of the hymenium showing asci and paraphyses.

(*b*) *Microsphaera or lilac mildew.* (*Optional.*) Observe the upper surface of the infected leaves and note little dark

scattered over the upper surface of the leaf, the
rps.
move some ascocarps from a leaf and mount in water
lide. Crush the ascocarp slightly by tapping on cover
Note its cellular structure and the shape, attach-
and arrangement of the **appendages.** Note the thin-
l sacs, the **asci,** which protrude from the broken
arp.
. How many spores do you find in each ascus?
tch an ascocarp on page 187, Fig. 125, to show the
features.

ss Basidiomycetes. This group ranks second to the
nycetes in number of species and includes a great
ty of forms and structures.

Wheat rust (*Puccinia graminis*). Examine the leaves
tem of a wheat plant that has been invaded by wheat
Note the reddish patches, the **uredosori,** made up of
erous **uredospores.** Mount some of these spores in
r on a slide and study under the microscope. Examine
stems of wheat collected in late summer. Observe the
k patches or **teliosori** containing the **teliospores.**
nt some of these spores in water on a slide and study
n under the microscope.
udy prepared slides of germinating teliospores. Make a
ch on page 187, Fig. 126, of the **promycelium** with its
gmata supporting the **basidiospores.**
xamine dried leaves of a barberry bush infected by the
. Note the rust-colored patches, the **aecia** or **cluster**
s on the under surface of the leaf. Study prepared slides
ross sections of the barberry leaf. Look for a section of
ecium or cluster cup and observe the chains of **aecio-**
es.
04. Prepare a diagram of the life cycle of wheat rust.
time permits, examine the different stages of other
s, such as the cedar-apple rust, white pine blister rust,
the rust of hollyhock.

b) Agaricus or field mushroom. Examine the plant pro-
ed.
05. What is the habitat of mushrooms?
06. What part of the mushroom is submerged in the sub-
atum?
07. What is the general form of the mushroom?
08. Why have these sometimes been called the "gill
gi"?
The umbrella-like structure is called the **pileus.** The
eus is supported by a stalk called the **stipe.** Underneath
pileus is found a series of plates called **gills** or **lamellas,**
vering which is a spore-bearing layer, the **hymenium.**
On page 189, Fig. 127, complete the drawing of a mush-
om, showing the above structures.
Under the demonstration microscope study a section
rough the gills.
609. How are the spores borne?

(*c*) *Fomes or bracket fungus.* This form of fungus is closely related to the mushroom.

610. What is the habitat of *Fomes?*

611. Where is the mycelium?

Observe the under side of the "bracket" with a lens and note the small openings or **pores** from which the spores escape. Observe in section the tubes in the porous layer lined by the hymenium which bears the spores.

On page 189, Fig. 128, make a drawing to show the above features.

PHYLUM BRYOPHYTA

The bryophytes are higher types of plants than the thallophytes, approaching more nearly the structure found in the higher plants. In the liverworts, or Hepaticae, the plant body is termed a thallus since it resembles the thallophyte in not having true roots, stems, and leaves. The mosses, or Musci, are more highly organized than the liverworts and have stems and leaves superficially resembling those of the higher plants. Both liverworts and mosses are closely related by the similarity of their reproductive organs and the stages of their life histories.

Liverworts. Class Hepaticae. These are amphibious plants for the most part and are found on moist soil, wet banks, old logs, trunks of trees, and overhanging rocks along the borders of streams. They get their name from the fancied resemblance of some forms to the human liver.

(*a*) *Marchantia.* Study the specimens provided.

612. What is the method of growth of the thallus?

Observe with a hand lens the ventral surface of the thallus.

613. What structures do you find?

(*b*) Examine a prepared slide of a section of the thallus under the demonstration microscope.

614. Do you find anything on the dorsal surface of the thallus that corresponds to stomata and the green mesophyll tissues of the leaves of higher plants?

Sometimes small cup-like structures will be found on the thallus called **cupules** which have small bodies in them called **gemmas.** These gemmas are shed and give rise to new plants asexually.

On page 190, Fig. 129, index the drawing to show the structures just observed. Label accurately.

The antheridia are found on special structures which are shaped somewhat like a toadstool with a slender stalk supporting a disk on the top. These structures are the **antheridial receptacles.** The antheridia are found embedded in the top of the disk.

(*c*) Now examine a prepared slide of the antheridia of *Marchantia.* The **antheridium** is found to consist of a short stalk bearing an oval **sperm case.** The **sperms** are produced in this sperm case.

On page 191, Figs. 130 and 131, complete the sketch of an antheridial receptacle, showing the structures just described.

The slender, stalked structures, resembling somewhat the antheridial receptacles but having, instead of a disk, a number of finger-like processes, are the **archegonial receptacles.** The **archegonia** are found on the under side of these processes.

(*d*) Examine a prepared slide of the archegonial receptacle. The **archegonia** are flask-shaped structures of which the large rounded portion is the **venter** containing the **egg.** Leading from the venter is the narrow **neck.**

On pages 191 and 193, Figs. 132 and 133, complete the drawing of an archegonial receptacle, showing the structures just described.

(*e*) Study a prepared slide of a sporophyte of *Marchantia.* The **sporophyte** is a stalked structure bearing a globular **capsule.** The sporophyte is attached to the gametophyte by a **foot,** which is an enlargement at the lower end of the **stalk** or **seta.** Note with high power the **spores** in the capsule and among the spores small filaments called **elaters,** which aid in the distribution of the spores.

615. Describe the appearance of the walls of the elaters.

On page 193, Fig. 134, complete the prepared drawing of the sporophyte, showing the above features.

On page 193, Fig. 135, construct a diagram showing the alternation of generations in the life cycle of *Marchantia.*

The mosses. Class Musci. Examine the plants provided.

616. What is the usual habitat of mosses?

617. What advantages do mosses derive from their growth habits?

Observe the parts of the plant body and compare them with those of the seed plants.

618. Is there a central axis?

619. Are there any leaf-like structures?

620. Are roots present?

(*a*) Mount a leaf of a moss plant in water on a slide and examine with high power of the microscope. Note the **chloroplasts** in the cells.

621. How does the moss leaf differ from the leaves of higher plants?

On page 195, Fig. 136, complete the drawing of a moss leaf as seen under the microscope. Index **mid-rib** and **chloroplasts.**

(*b*) Examine prepared slides of the tops (rosettes) of moss plants. Study sections of **archegonia** and **antheridia.** In most species these are found on separate plants.

On page 195, Fig. 137, complete the drawings and index accurately.

(*c*) The leafy shoot of the moss plant bearing the sex organs is the **gametophore,** which is a part of the gametophytic generation. Some of the moss plants bear a rod-like structure whose distal end is enlarged to form a **capsule.** The slender rod is the **seta.** The entire structure, with the exception of a thin covering of the **capsule (calyptra)** which may have been lost, is the sporophytic generation. Note the small cover, the **operculum,** on the top of the capsule.

Place the capsule of the sporophyte on a slide in water and tear it lengthwise with a needle. Spread it out on the slide, add cover glass, and examine under the microscope. Note that underneath the operculum there is a row of teeth surrounding the opening.

622. What is the function of these teeth?

The teeth are attached to a ring-like thickening (**annulus**) of the capsule and make up the **peristome.**

(*d*) Note the small brown **spores** which have been expelled from the capsule. Upon germination the spore produces a branching green filament, the **protonema.** The gametophore is an aerial branch of the protonema; therefore these two structures represent the gametophytic generation. Complete the drawing of the sporophytic structure on page 195, Fig. 138. Include several teeth of the peristome.

623. Compare the Hepaticae and the Musci.

On page 197, Fig. 139, construct a diagram showing alternation of generations of the moss.

PHYLUM PTERIDOPHYTA

These are true land plants, including the ferns, horsetails, and club mosses. Their organization is very similar to that of the higher seed plants. In this group of plants the sporophyte is well defined and becomes independent.

True ferns. (*Filicales.*) The ferns usually grow in a moist soil, rich in humus, and in shady places. In the stems of ferns we find true vascular tissue (phloem and xylem).

(*a*) Examine the growing fern. Determine the position of the stem and its habit of growth, whether upright or creeping. Study the arrangement of the **fronds** or leaves. Study fruiting fronds bearing on their surface minute brown **sori** (singular, **sorus**) variously arranged in different species of ferns.

Note the **roots** on the stem. Study the fronds or leaves consisting of a **leaf stalk** and **blade.**

624. Describe the branching of the **veins.**

Observe a very young leaf and note its apparently coiled tip. This is known as **circinate vernation,** which is characteristic of all ferns. Observe more closely the sori on the surface of the leaves. Each sorus consists of a cluster of **sporangia** generally covered by a protective membrane, the **indusium.**

On page 199, Fig. 140, complete the habit sketch of the plant to show the above features.

(*b*) Scrape off some of the sporangia from a sorus and mount in water. Study the sporangia under high power.

On page 199, Fig. 141, draw a side view of a sporangium from which the spores have been discharged. Show in the

g the **stalk,** the **spore case** with its row of thick-walled ong the margin, forming the ring or **annulus,** and the free or enclosed in the sporangium.

fact that the fern plant, as commonly recognized, has ual organs but produces spores only (asexual repro- n) makes it a sporophyte.

The green plate-like structure developed from a spore ed a **prothallium.** Note the position of the root-like ures or **rhizoids.** At the basal or more narrow end of othallium note the small, globular **antheridia,** which ce the **sperms.** Just back of the notch, on a thicker of the prothallium, are the projecting necks of the gonia, which bear the **eggs.**

page 199, Fig. 142, complete the drawing of the pro- um to show the structures seen above.

ce the prothallia bear sex organs and reproduce sexu- hey are the **gametophytes.** From the zygote in the gonium of the gametophytic plant grows the new fern which reproduces asexually by means of spores and ed the **sporophyte.**

page 201, Fig. 143, construct a diagram of the life cycle, ng the alternation of generations seen in the fern.

rsetails. Equisetales. (*Optional.*) These plants have l-defined alternation of generations. The **sporophyte** is the most prominent and is independent of the **tophyte.** These plants have a number of xerophytic acters. The **whorled leaves** are small, scale-like, and ionless. The vascular system is poorly developed. aerial green stems grow from an underground root stock **izome** similar to that of the ferns.

uisetum. Note that the green stems arise from an un- round stem or **rhizome.** The aerial stems are seg- ed into **nodes** and **internodes.**

5. Where do you find the hard, scale-like leaves?

) On the end of the stem, note the **cone** or **strobilus.** small polygonal scales making up the strobilus bear the **angia** and are therefore called **sporophylls.** Remove sporangia, mount in water on a slide, and crush be- h a cover glass. Note the coiled **elaters** attached to the **es.**

n page 203, Fig. 144, complete the sketch of the plant to v the above features.

) Make a cross section of a stem of *Equisetum.* Observe large **air spaces** and the distribution of the green tissue. rigid tissue is found around the outside, and just inside are the **vascular bundles.**

lub mosses. Lycopodiales. In this group the sporophyte dependent, and alternation of generations is well defined. plants are low and creeping, with horizontal branching s and small, scale-like leaves.

ycopodium. Note the upright branches bearing the lle-shaped **leaves.** The terminal **strobili** borne on the ends of the branches are made of spirally arranged leaves, or **sporophylls** with **sporangia** at their bases, one sporangium on each sporophyll. Remove a sporophyll and examine it with a hand lens.

On page 203, Fig. 145, make a careful drawing showing the sporangium.

Examine the contents of a sporangium.

626. Are the spores all alike?

627. What do we call this condition in a plant?

Selaginella. Note the arrangement of the leaves. Study the **strobilus** of *Selaginella.* The **leaves** here are close together; attached to their bases are small bodies, **sporangia,** which bear **spores.**

628. How many kinds of sporangia do you find?

629. Are these on the same part of the strobilus?

The smaller spores are called **microspores** and ultimately produce the **male gametes.** The larger spores are called **megaspores** and ultimately produce **female gametes.**

630. What do we call this condition in a plant?

Compare *Selaginella* and *Lycopodium.*

On page 205, Fig. 146, index a portion of a plant showing the method of growth and the general features of the **strobilus;** draw a **megasporophyll** with the **megasporangium;** draw a **microsporophyll** with the **microsporangium;** and draw a **microspore** and **megaspore,** showing the relative size of each.

On page 205, Fig. 147, are prepared drawings of the male gametophyte, the female gametophyte, and the embryo sporophyte of *Selaginella.* Index these accurately.

Review the sketches made in your study of *Marchantia,* moss, fern, and *Selaginella.* Color all gametophytic structures red and sporophytic structures blue.

PHYLUM SPERMATOPHYTA

These are the seed-bearing plants. Economically, they are the most important members of the plant kingdom. The phylum is divided into two groups, the gymnosperms and the angiosperms.

Gymnosperms. These plants are the familiar evergreen, cone-bearing shrubs and trees. Common types are the pines, firs, spruces, tamarack, hemlock, and junipers.

631. What is the nature of the habitat of spruces and pines?

632. How are they adapted for this mode of life?

633. What is the general shape of the tree?

634. Describe the leaves and their arrangement.

635. Of what advantage is this form of leaf?

(*a*) *The staminate cone.* Note the spiral arrangement of the scales called the **stamens.** (Prepared longitudinal sections of the cone may be studied here.)

On page 207, Fig. 148, diagrammatically show the arrangement of the stamens along the axis of the cone.

Remove a stamen from a cone and observe its form and structure. Note the short stalk and the **pollen sacs.**

On page 207, Fig. 149, make a careful sketch of the stamen and the pollen sacs. Split the pollen sac and mount some of the **pollen grains** on a slide. Examine with the microscope.

On page 207, Fig. 150, sketch the pollen grains.

Recall the asexual reproductive structures of *Selaginella.*

636. What structures of *Selaginella* are the homologues of the stamens, pollen sacs, and pollen grains of the pine?

(*b*) *Young carpellate cone.* Note the spiral arrangement of the cone scales. Study a prepared longitudinal section of a carpellate cone.

Sketch on page 207, Fig. 151, to show arrangement of **carpels** on the axis, and ovules on the carpels.

Carefully remove a carpel and note on its inner face two **ovules** each with a wing-like **appendage.**

On page 207, Fig. 152, draw a carpel with its ovules.

Study the mature cone and compare it with the young carpellate cone. Remove one of the carpels and examine the inner face. Note that the ovules are ripening into winged seeds and are separating from the scale or carpel.

On page 207, Fig. 153, sketch the inner face of a carpel with its ripened seed.

Recall the asexual reproductive structures of *Selaginella.*

637. What structures of *Selaginella* are the homologues of the carpels and ovules of pine?

Angiosperms. The plants in this group are familiar to us as the common flowering plants. The general structural features of this group have been studied previously at various times in connection with our consideration of the root, stem, leaf, flower, fruit, and seed. Now review all these structures by bringing your sketches together on one or two plates, in outline only. This must be done outside the laboratory period.

638. Bearing in mind what you have learned in your recent studies of plants, from what structures, would you say, have the parts of the angiosperm flower been derived?

CLIMATIC DISTRIBUTION OF PLANTS AND ANIMALS

The geographic distribution of plants and animals over the surface of the earth is largely governed by climate. Species having similar temperature and moisture requirements occur together in great regional groups. Study the map, page 209, Fig. 154, and use colored pencils to indicate the different climatic zones.

639. List three characteristic plants and animals of each zone.

640. In which zone are you living?

641. Record in the form of a graph the average temperature and rainfall per month for the region in which you live.

642. What is the elevation of your community?

LOCAL ECOLOGICAL STUDIES

DIFFERENT ENVIRONMENTS

(*a*) *Pond.* Visit a pond or small lake in your vicinity and study it carefully, recording your observations as suggested below.

Prepare a rough map of the pond (page 211, Fig. 155), showing the following zones or stages: (1) open water (if any); (2) floating vegetation; (3) emersed vegetation; (4) the grass-sedge meadow, or fen; (5) the shrub; and (6) the tree.

Under the direction of the instructor, observe and collect as many specimens as possible from the areas outlined above. These specimens should be carefully preserved so that they can be transported to the laboratory for further study and identification.

Now locate certain regions of the pond which will be designated as stations. If the pond has a stream entering it and one leaving it, two of the stations should be located in the pond near these points. Mark these places on the map as "stations," and in your collection records designate by number the station near which the specimen was found.

With a thermometer determine the temperature of the water at several places in the pond.

643. Do you note any difference in the temperature at the various stations?

Collect samples of water from your stations for determination of the amount of available oxygen.

Now summarize the results of the trip as follows:

644. List the plants found in the pond and at its margin (first three zones). Which species are most abundant?

645. List the animals found in the water. Do you find any relation between the oxygen content, the temperature of the water, and the animals found at various stations?

646. Do you find any correlation between the distribution of the plants and the distribution of the animals?

647. List conspicuous and abundant insects observed or collected in and near the water.

648. Discuss the relation of each to its habitat, especially with respect to food and shelter.

649. List any amphibians, reptiles, birds, and mammals observed near the pond.

Examine under high power of the microscope a sample of water from the pond. Locate and sketch a few forms of plankton, microscopic plants and animals. Attempt to identify some of them, using Fig. 156, page 213.

0. Of what importance is the plankton in the order of re?

) *Running stream.* Proceed as in the pond study to e a survey of the plant and animal life of a running m.

1. Compare the animal and plant life of the running m with that of the pond or lake.

) *Field.* Visit an open field used as a pasture or meadow number of years. Describe this habitat, using the fol- ng outline.

52. What is the character of the soil (sand, loam, or)?

53. Test samples of soil for acidity. Record results.

54. Would you say the habitat is moist, dry, or medium?

55. What are the dominant plants?

56. What is the average height of the tallest plants?

57. What are the dominant animals?

58. List the animals which you observe and group them ording to phylum and class.

59. What animals live in the soil as burrowing animals?

60. What food relations do you observe?

61. Select five animals and describe the method of pro- tion from enemies they possess.

(*d*) *Forest.* Visit a forest in your neighborhood and describe it in detail, as suggested below.

662. What is the character of the soil (humus, clay, sand, shale, limestone)?

Test a sample of soil for acidity.

663. Record results.

664. Are there many snails present? What relation to soil acidity or alkalinity would the relative abundance of snails bear?

665. What are the most prominent and common trees?

666. What, approximately, is their average height?

667. Are there smaller trees or tall shrubs forming a layer beneath the tree canopy?

668. What species are represented?

669. List several species of herbaceous plants growing in the shade.

670. What kinds of plants are found upon the soil or on decaying logs?

671. List the principal kinds of animals observed and classify them as to the part of the habitat they principally occupy: in the tree tops, upon the surface of the ground, beneath the surface of the ground, or within and under rotten logs.

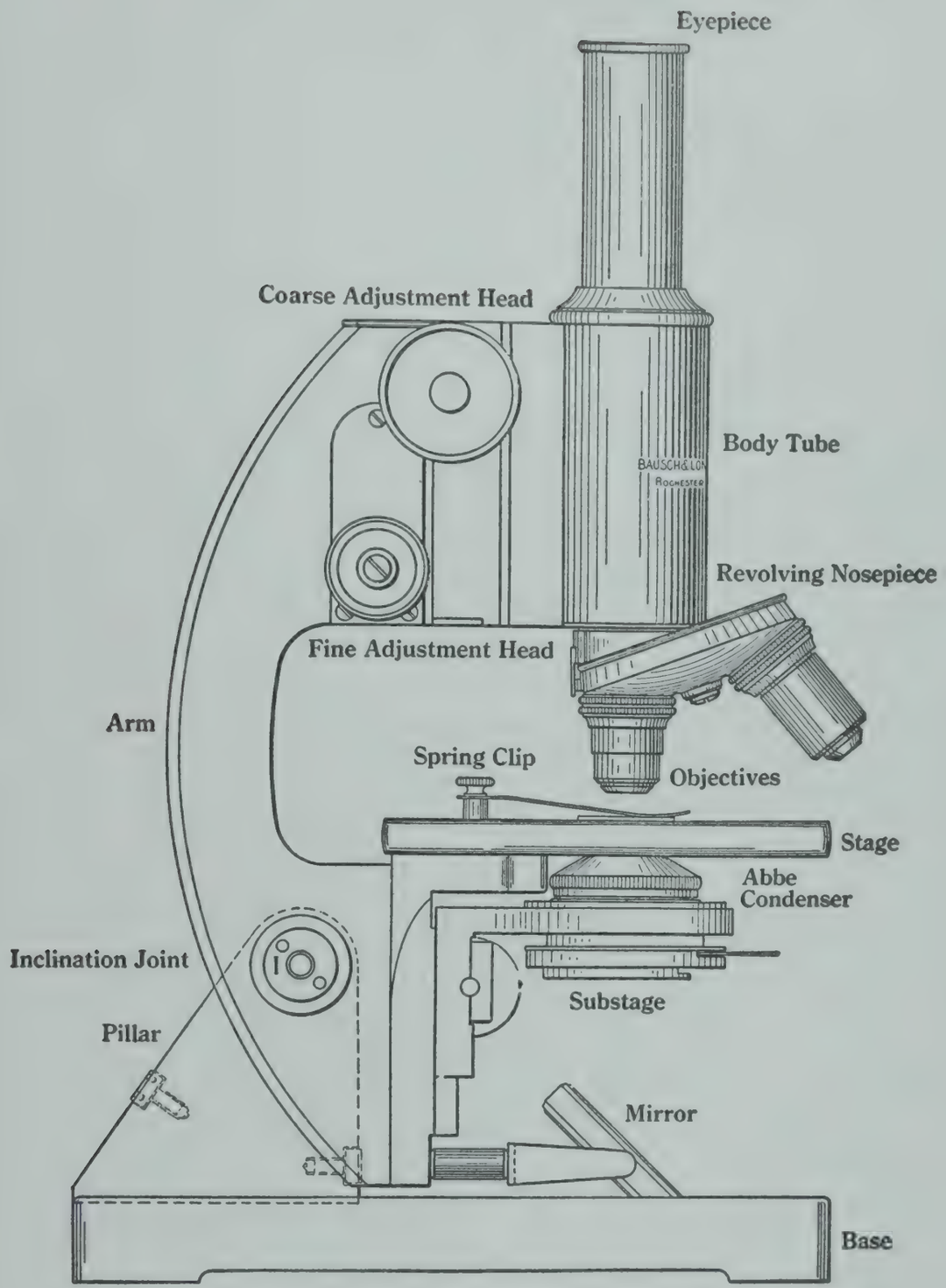


FIG. 1. Mechanical Construction of the Microscope.

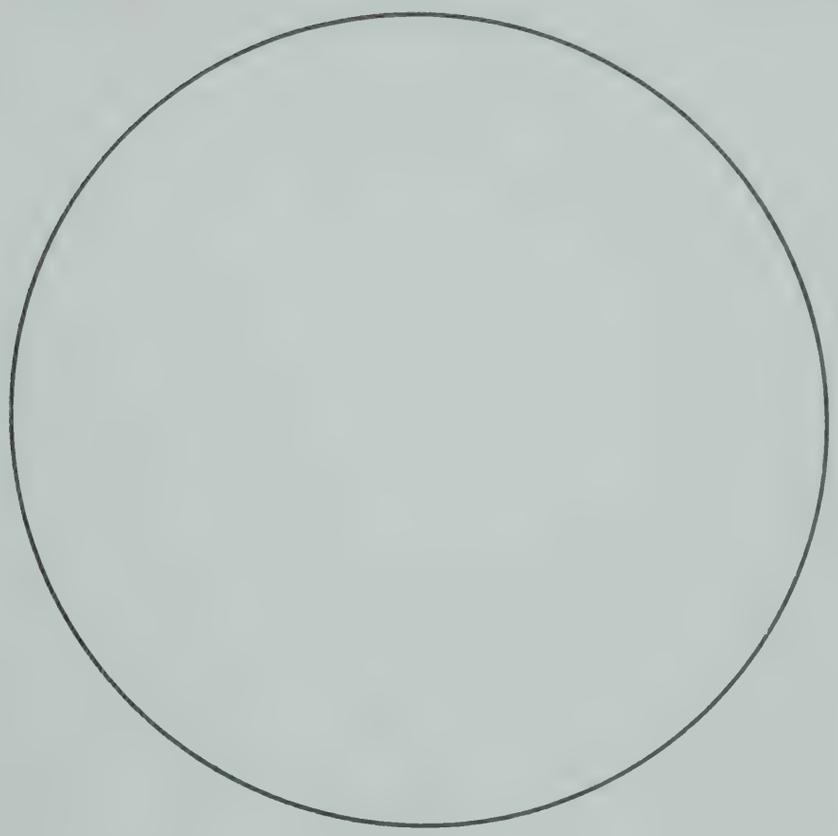


Fig. 2.

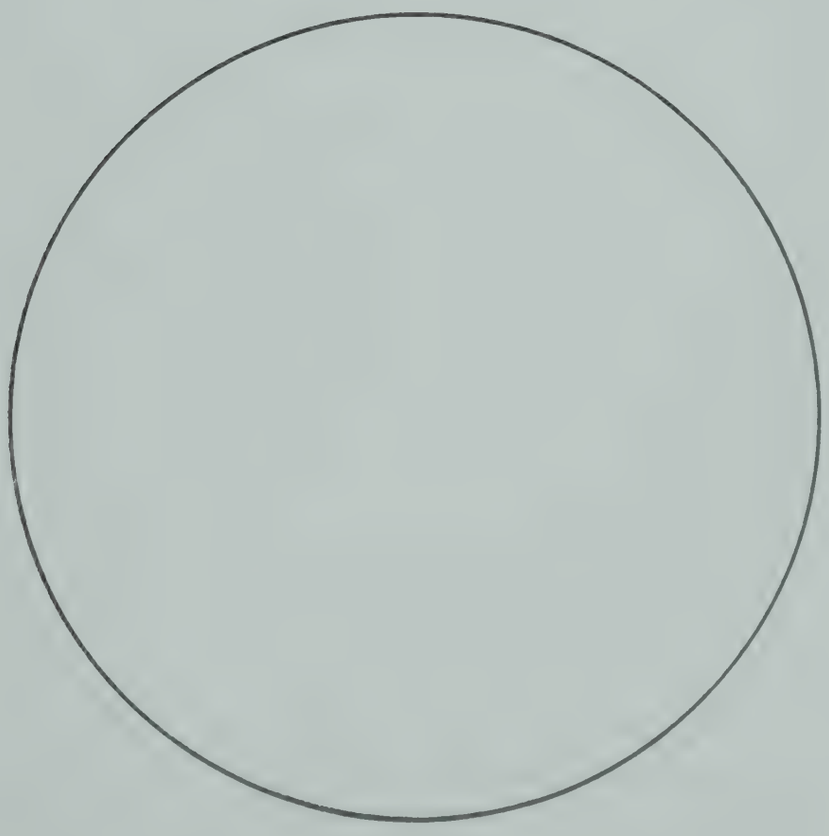


Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

FIG. 11.

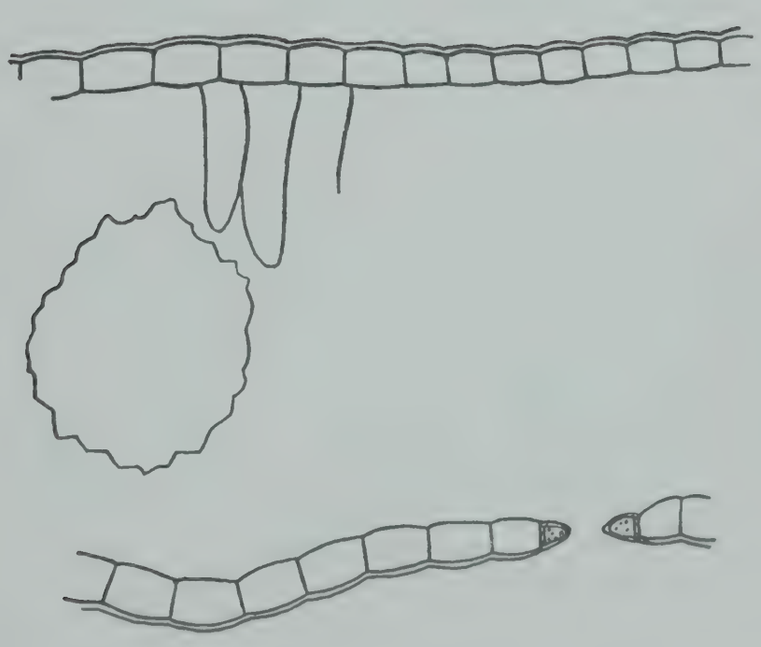
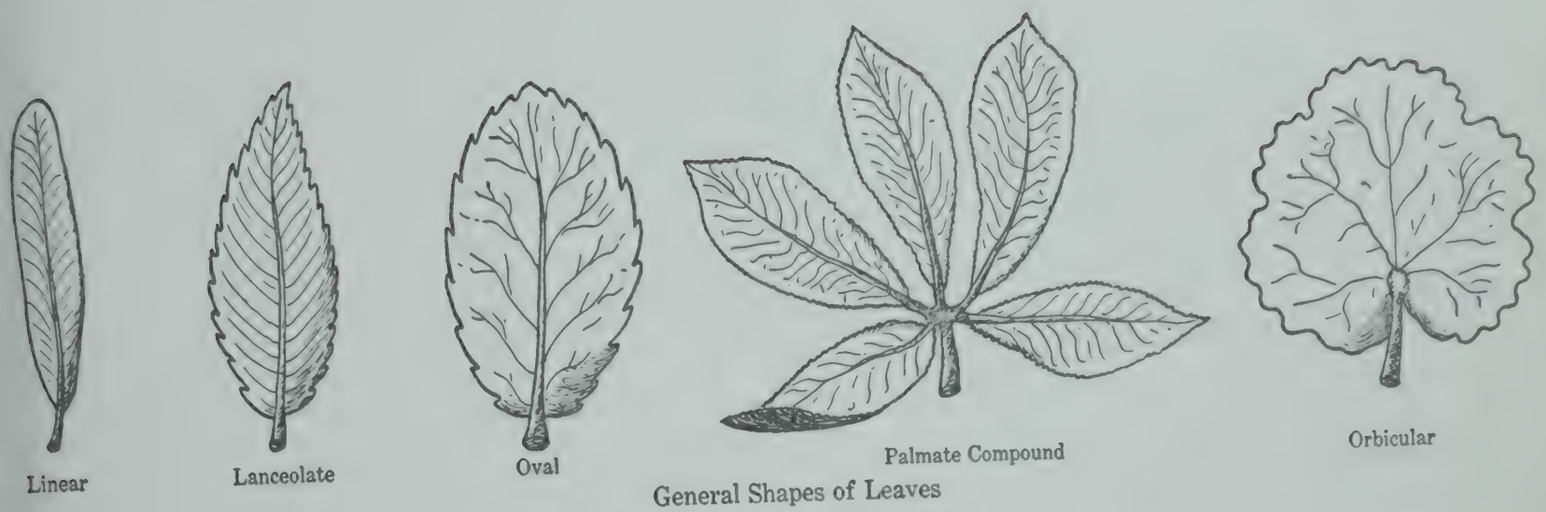
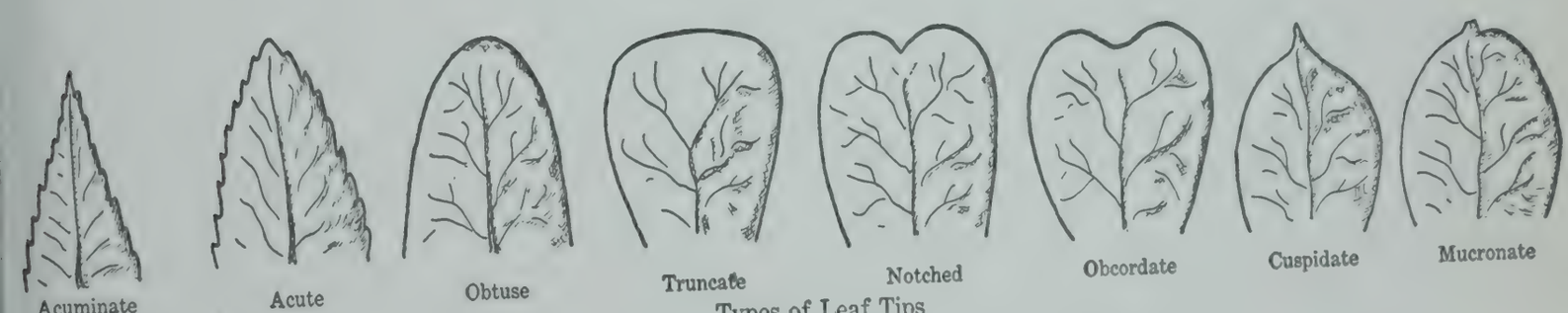


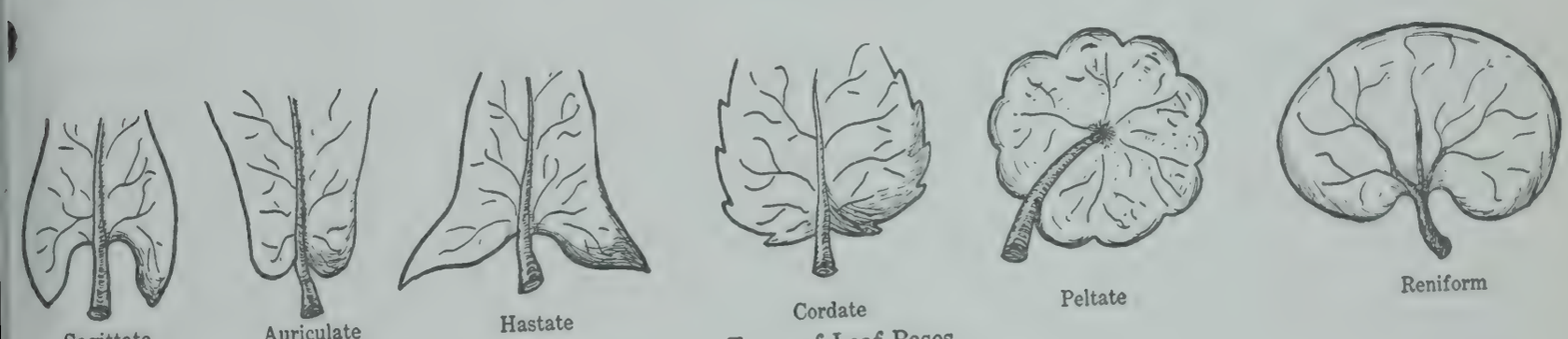
FIG. 12.



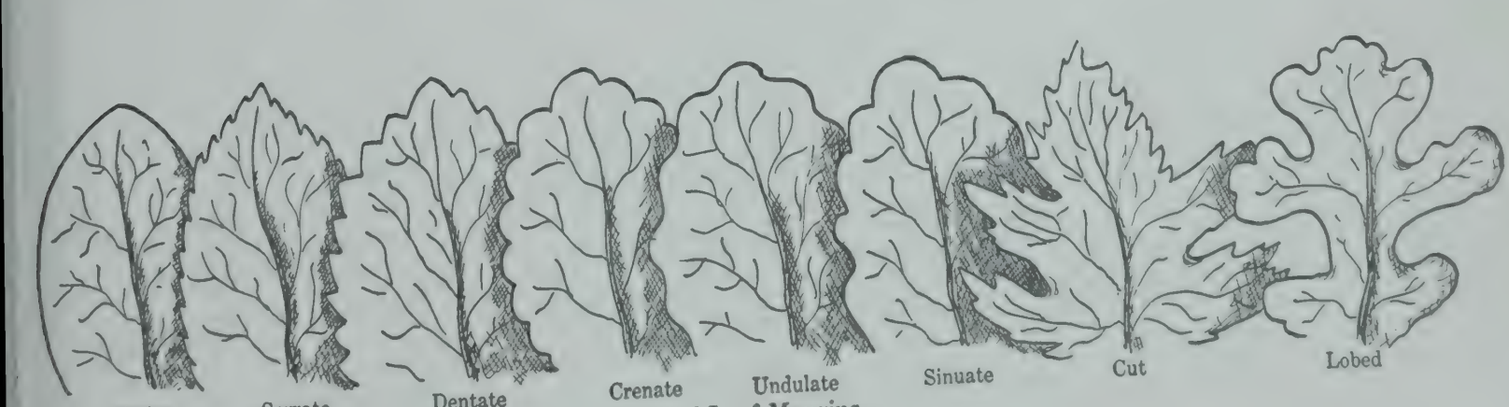
General Shapes of Leaves



Types of Leaf Tips



Types of Leaf Bases



Types of Leaf Margins

FIG. 13.

Fig. 14.

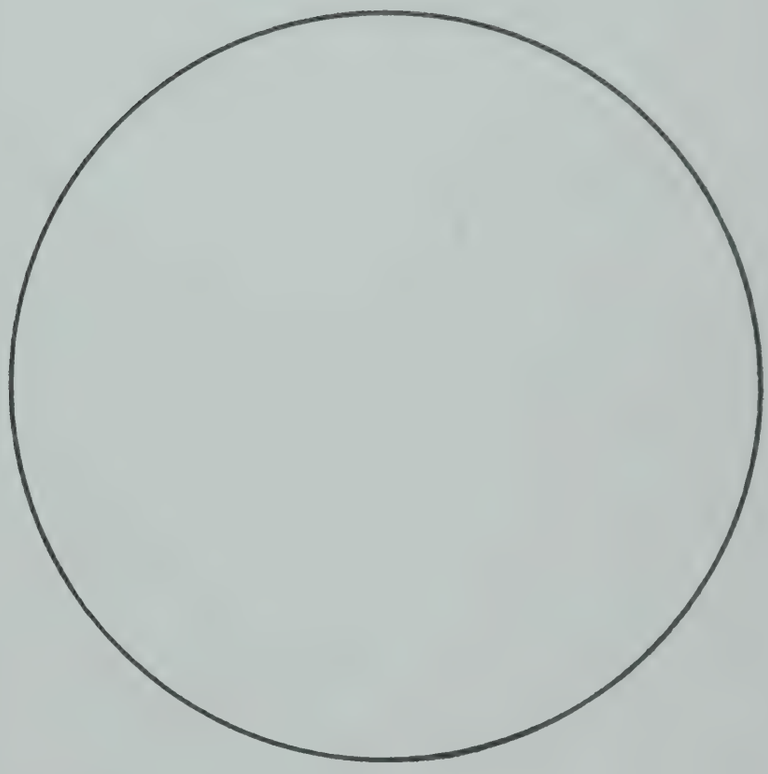


Fig. 15.

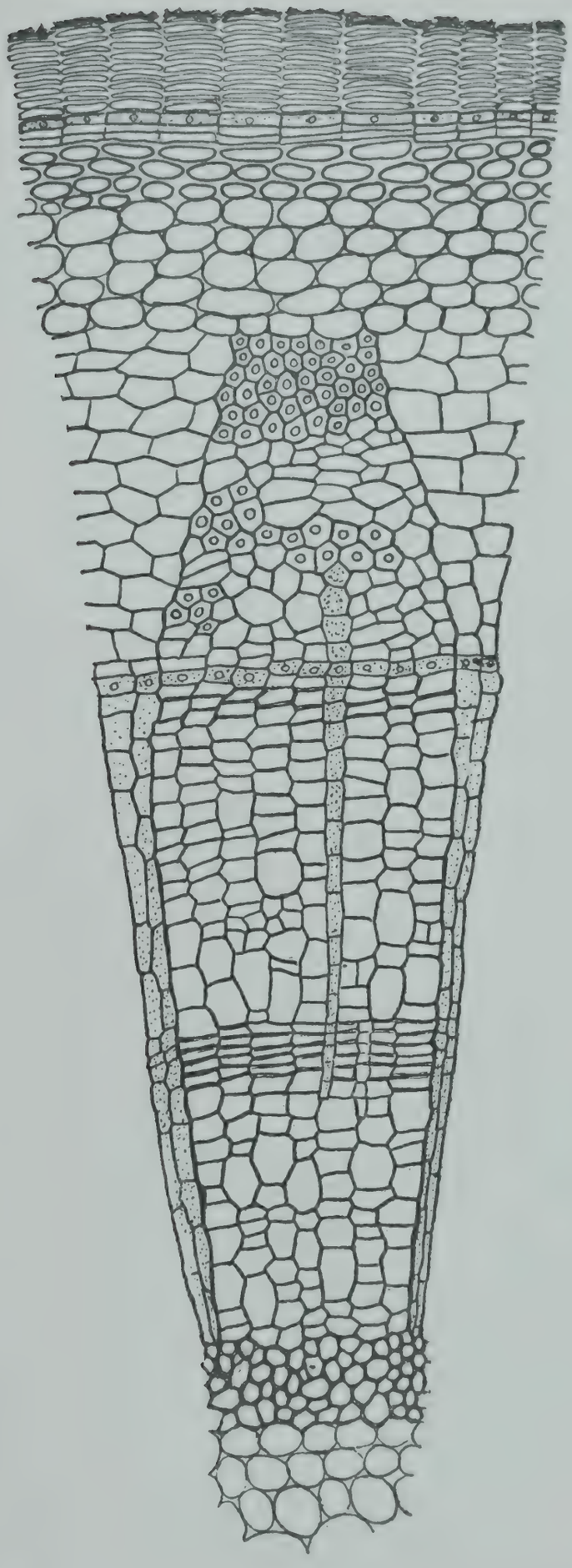


Fig. 16.

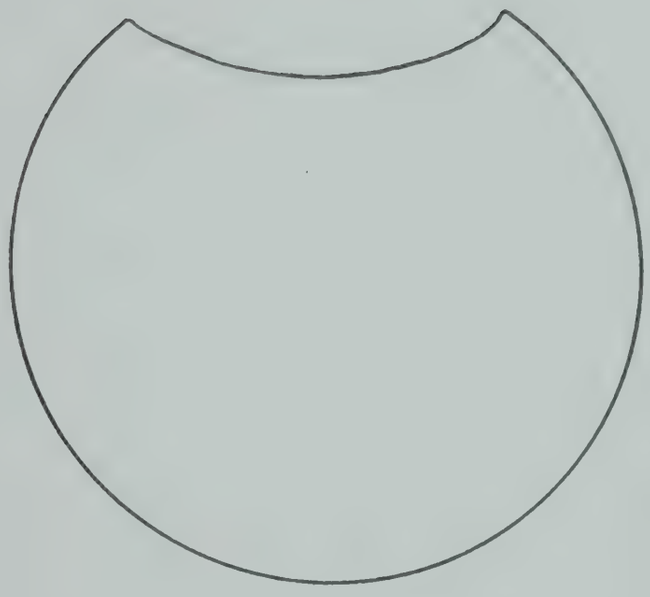


Fig. 17.

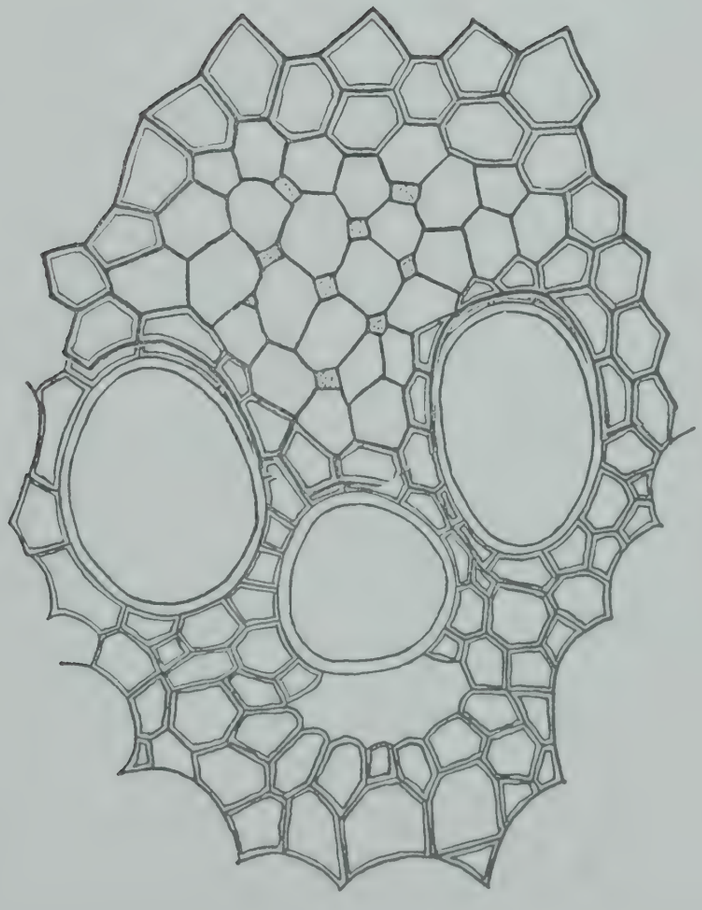


Fig. 18.

Fig. 19.

Fig. 21.

Fig. 20.

Fig. 22.

Fig. 23.

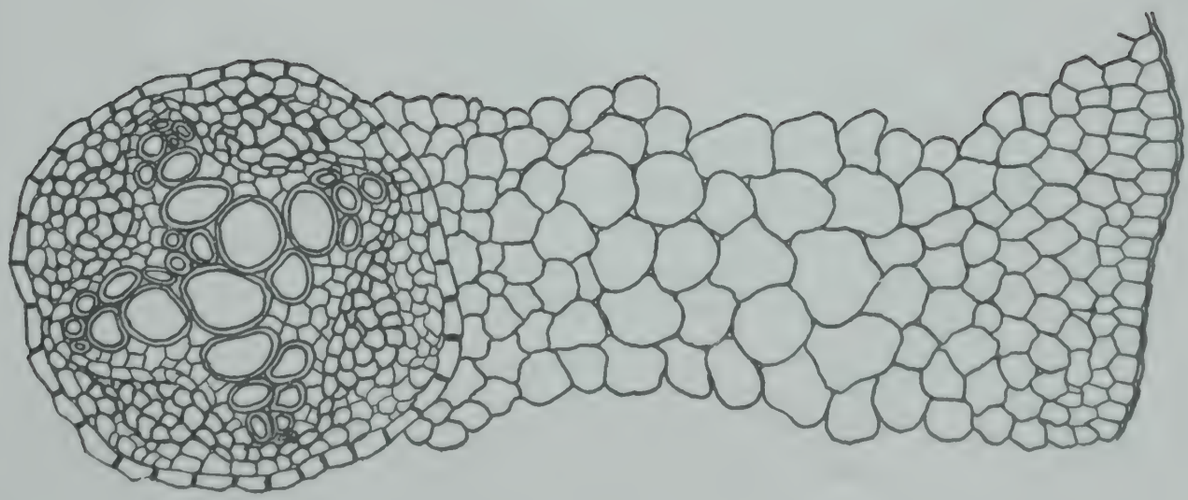


Fig. 24.

Fig. 25.

FIG. 26. Table for Food Tests

Food Tested	Starch	Sugar	Fat and Oil	Protein	Water
Ex: Irish potato	+++	−	−	+	++

FIG. 27.

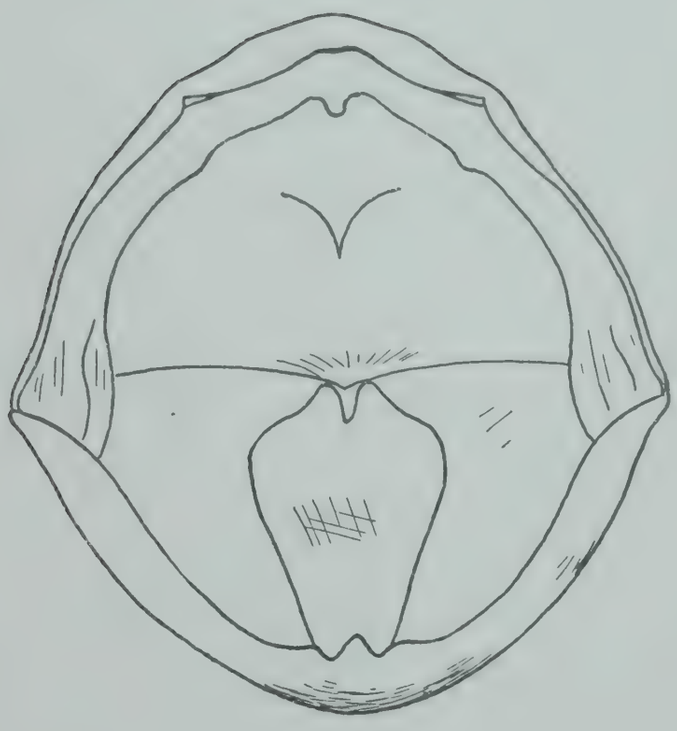


FIG. 28.

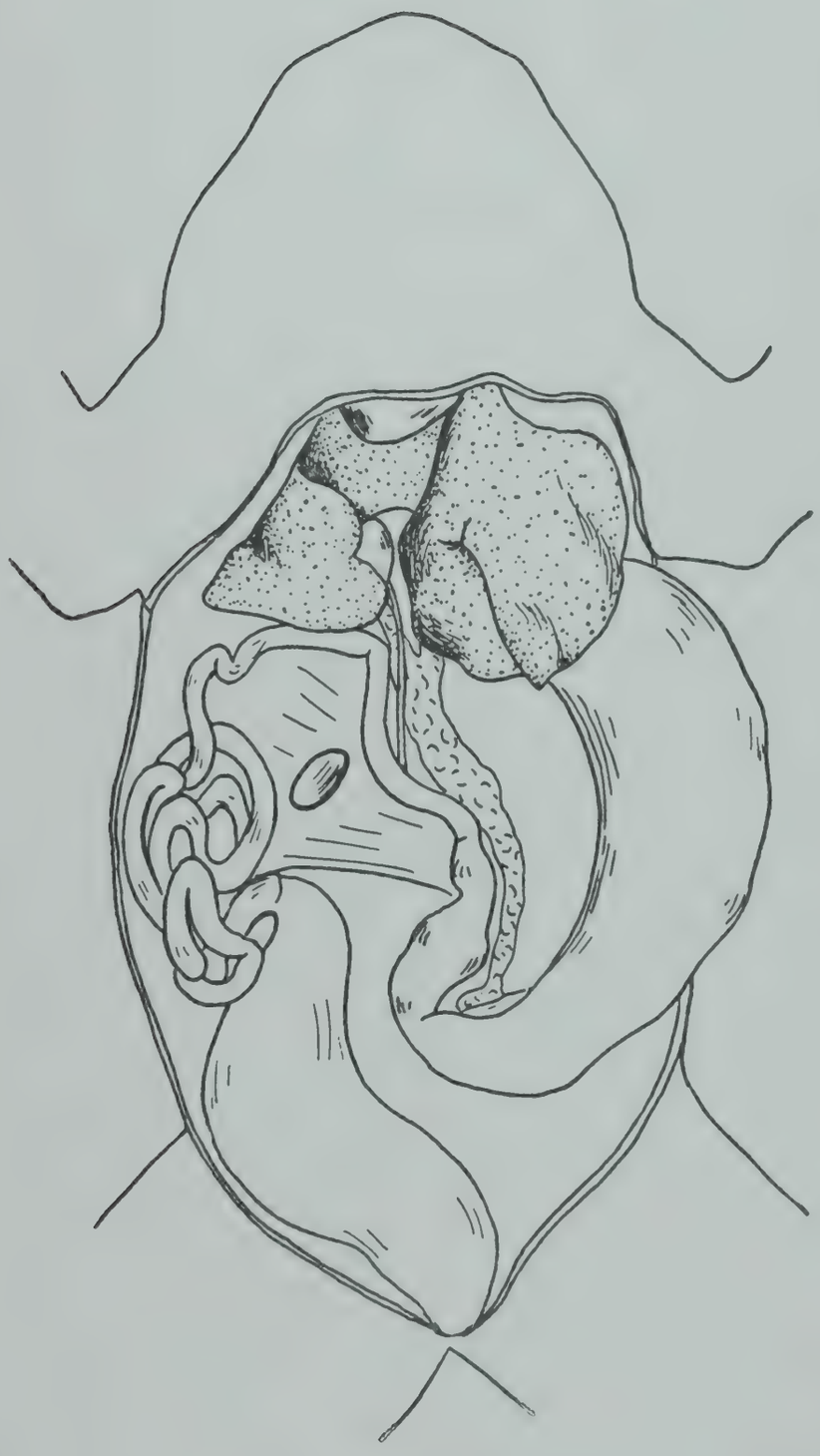


FIG. 29.

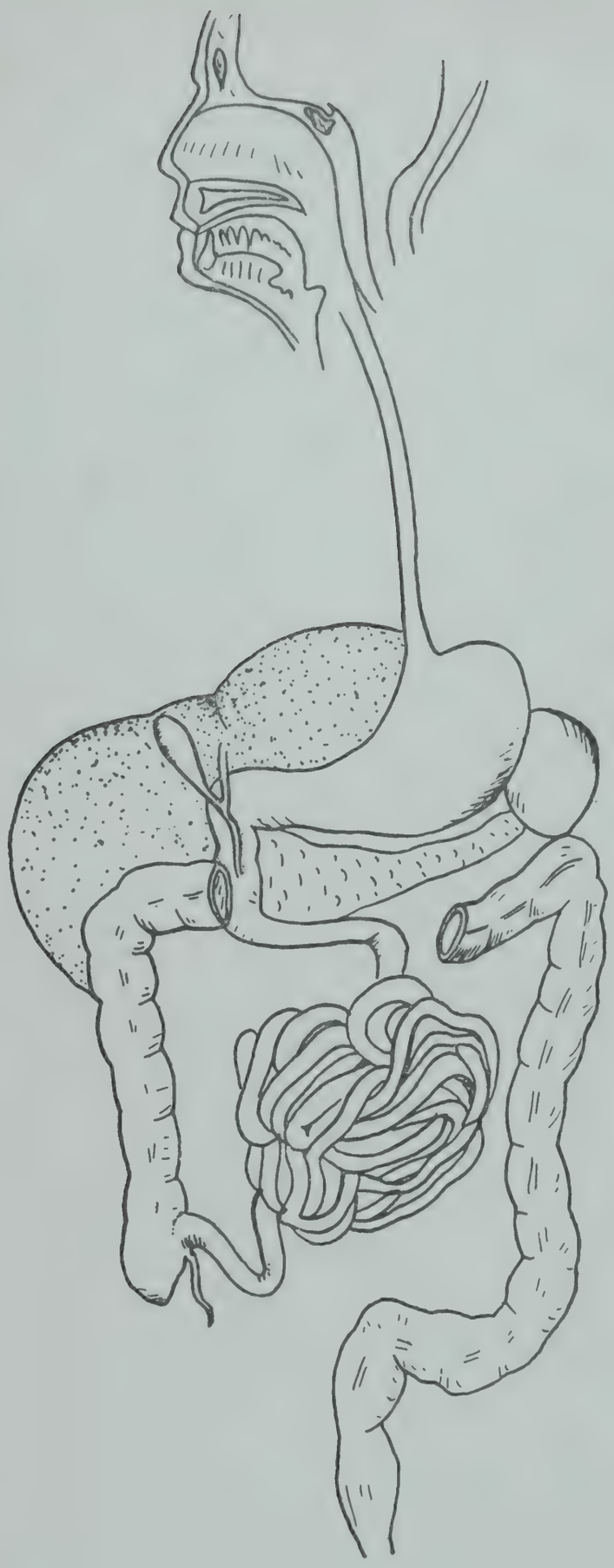


FIG. 30.

FIG. 31.

Fig. 32.

Fig. 33.

Fig. 34.

Fig. 35.

Fig. 36.

Fig. 37.

Fig. 38.

FIG. 39. Table for Summary of the Action of the Digestive Glands

Organ	Enzyme	Place of Action	Action
Ex: Salivary gland	Ptyalin	Buccal cavity	Starch to simple sugar

Fig. 40.

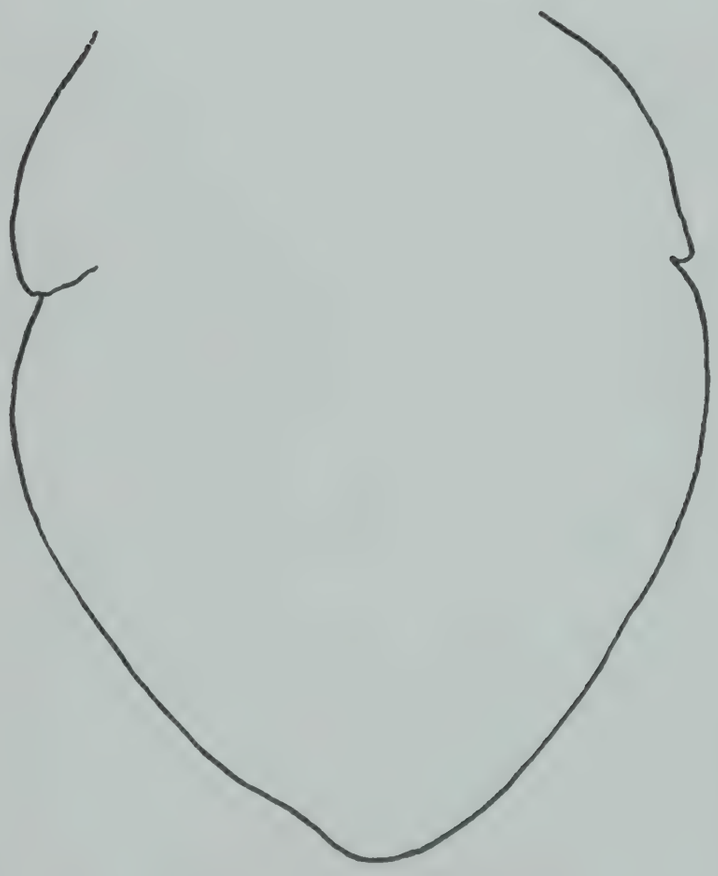


Fig. 41.

Fig. 42.

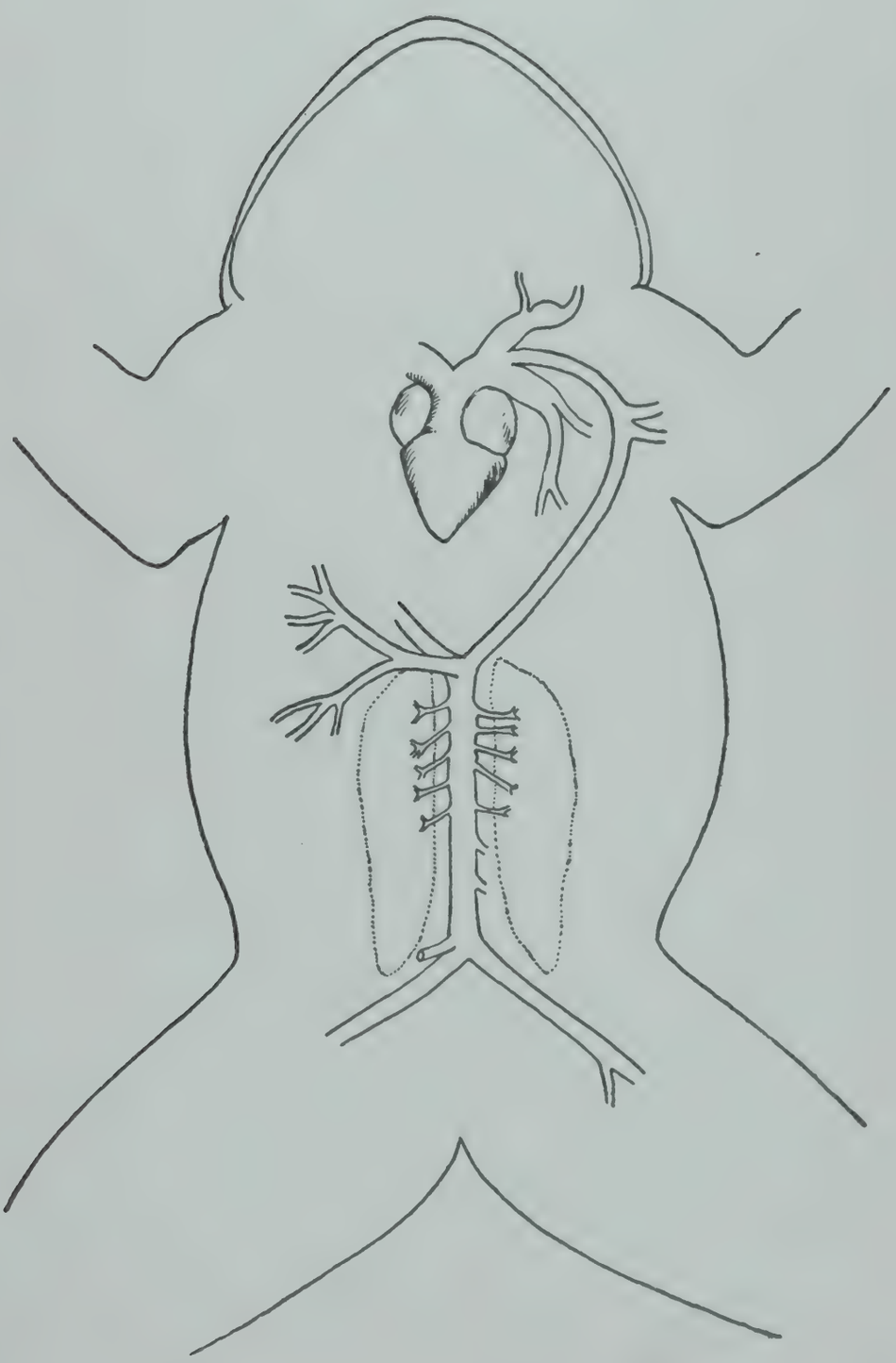


FIG. 43.

FIG. 44.

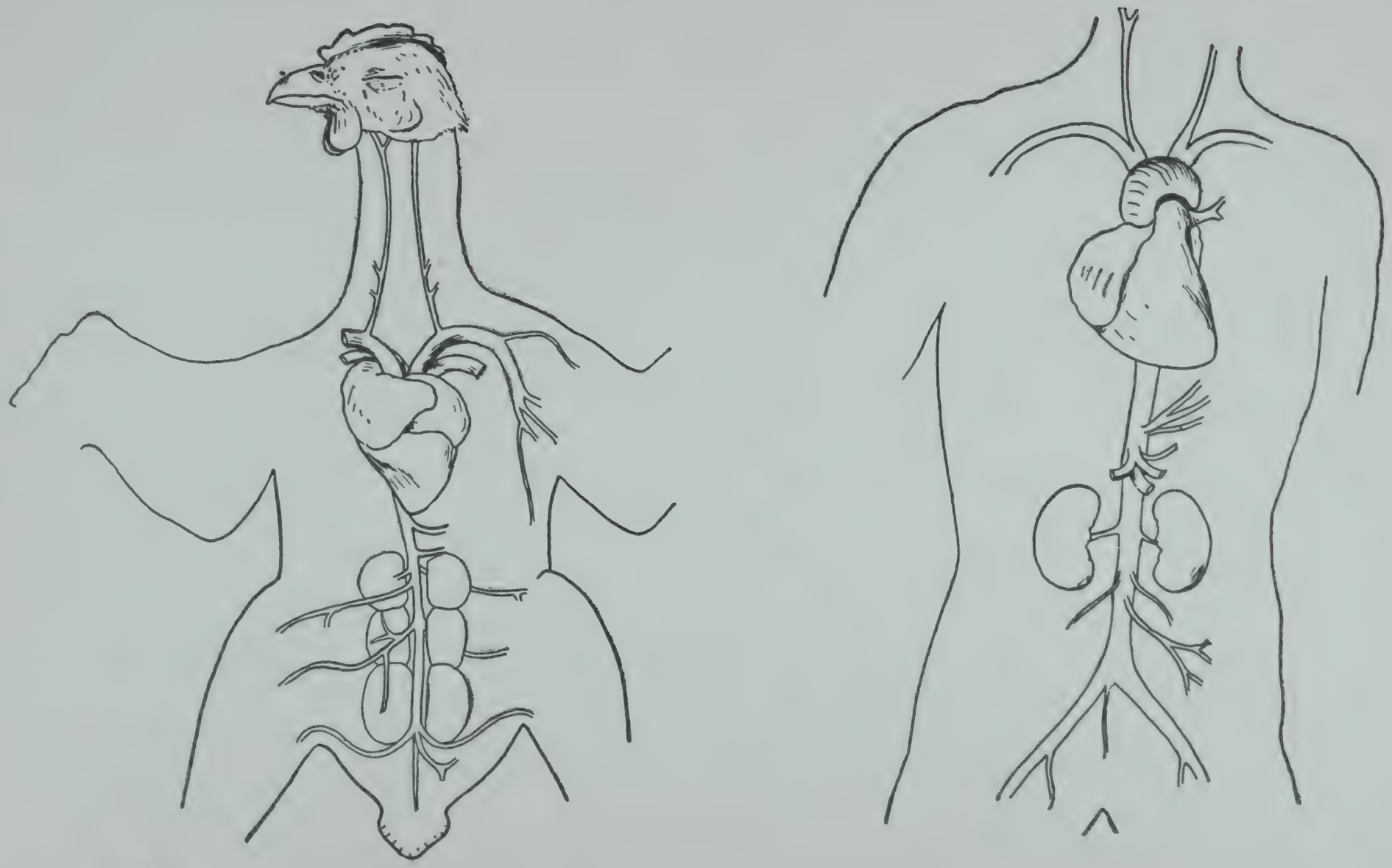


FIG. 45.

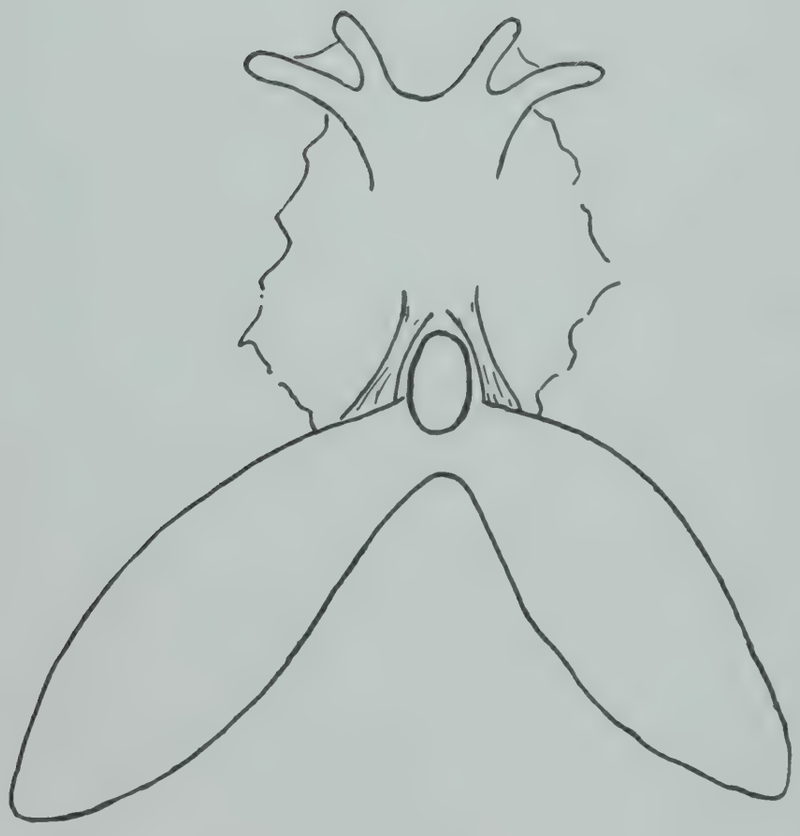


Fig. 46.

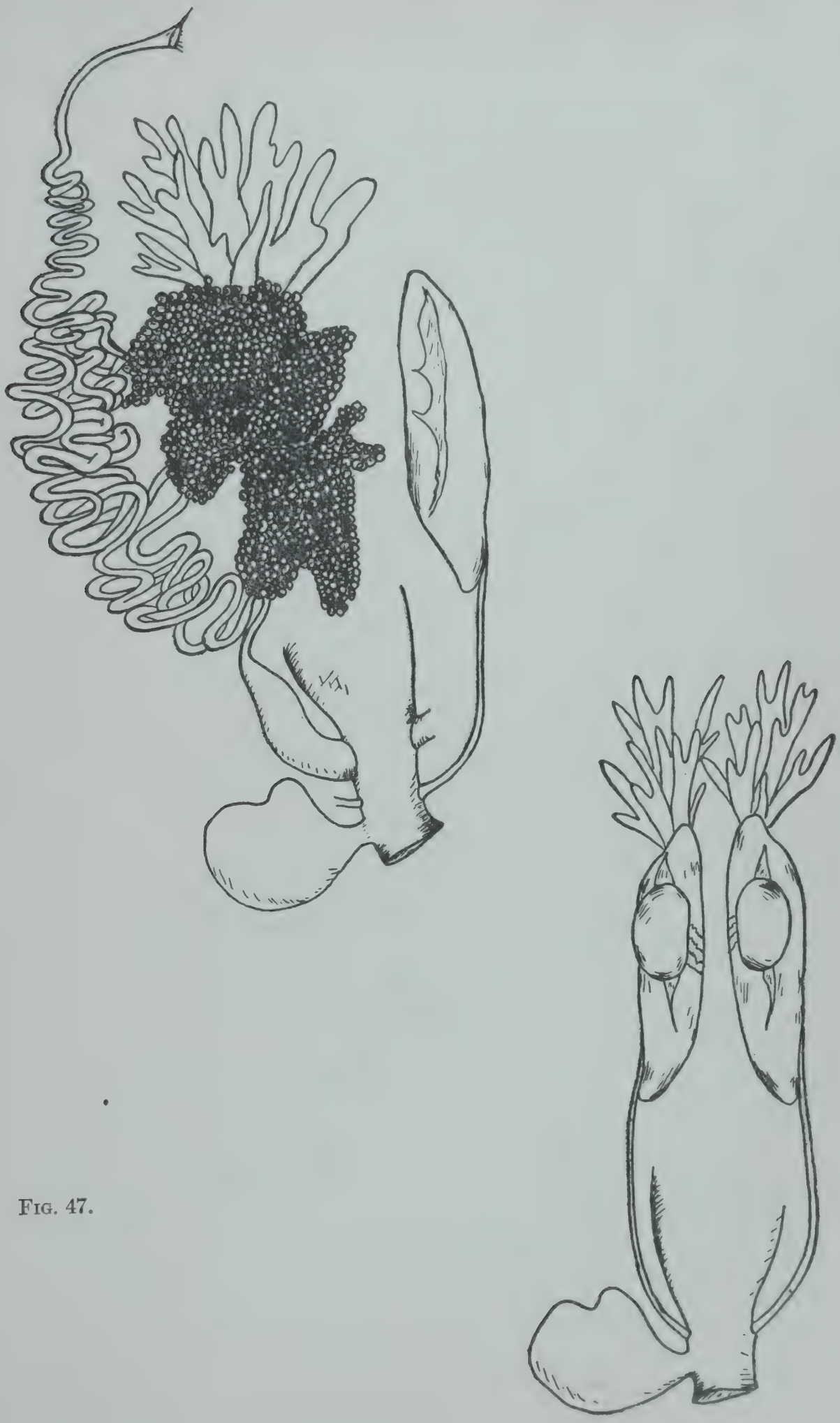


Fig. 47.

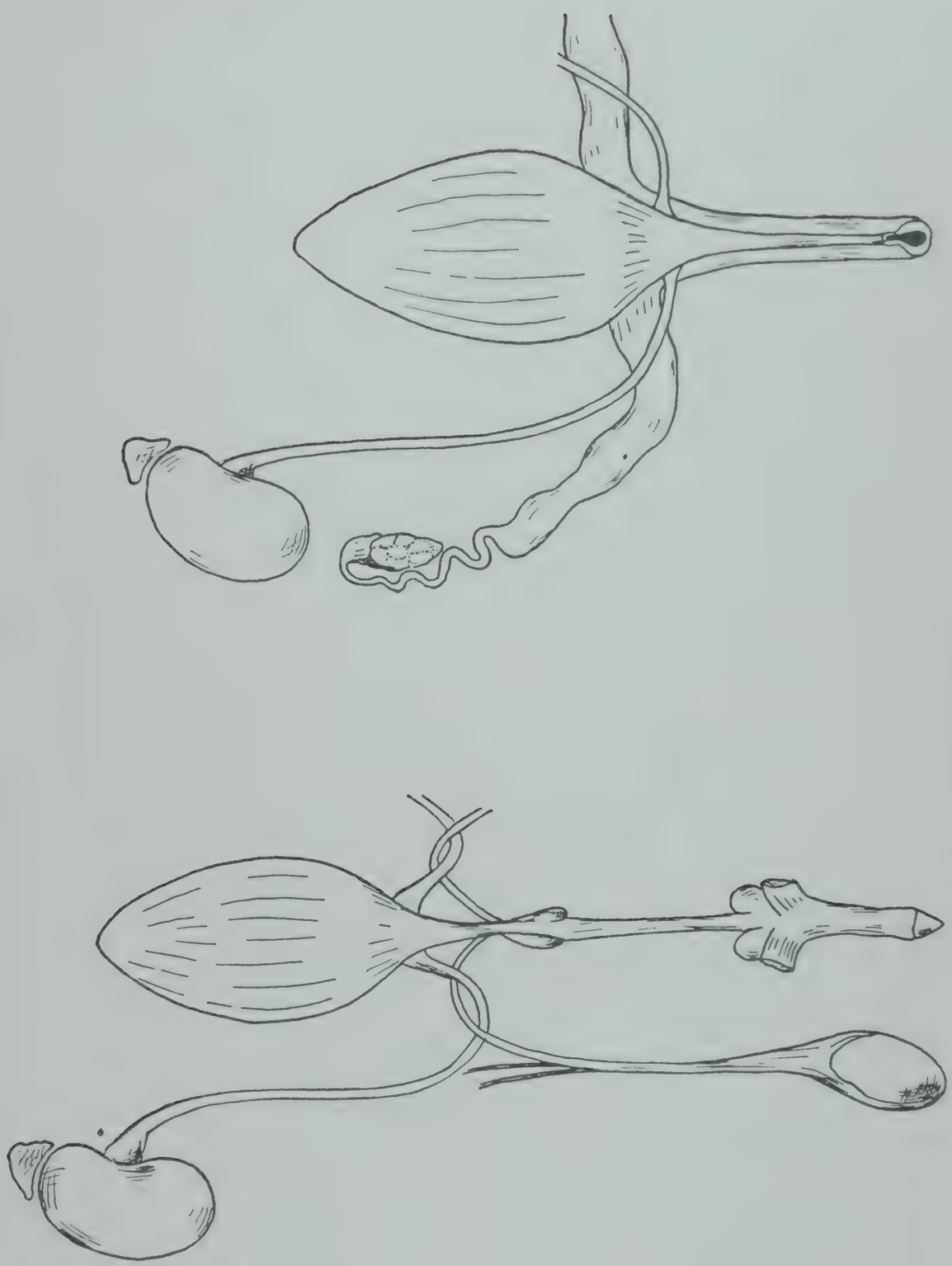


FIG. 48.

Fig. 49.

Fig. 50.

Fig. 51.

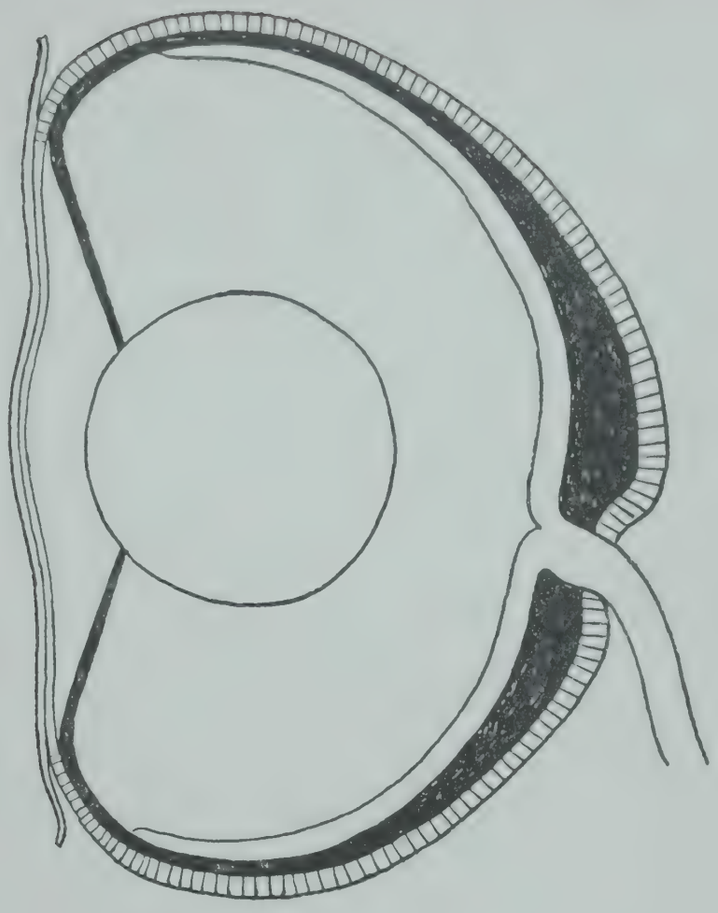


FIG. 52.

FIG. 53.

FIG. 54.

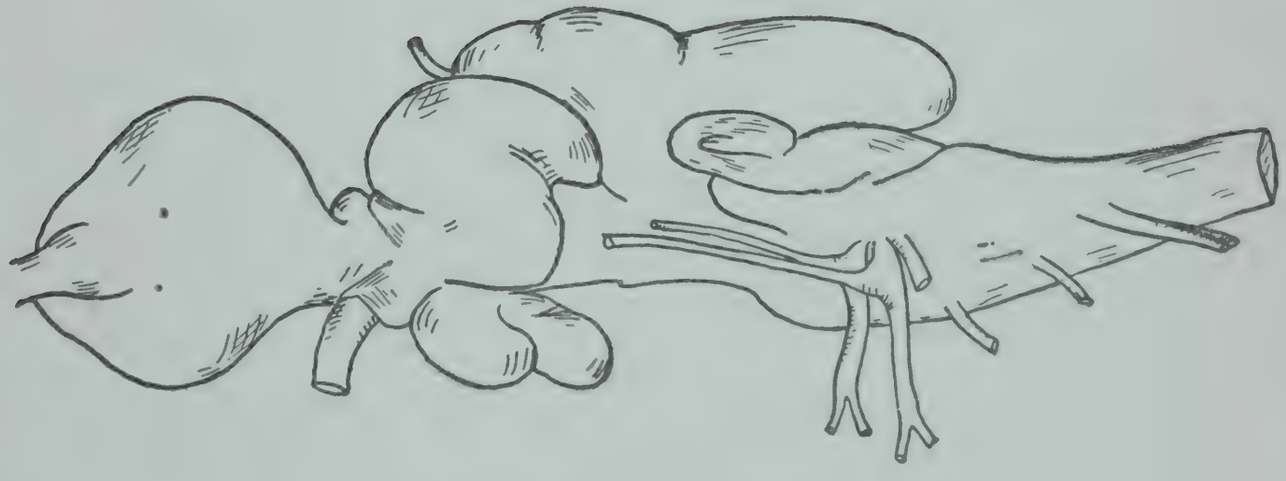


FIG. 55.

FIG. 56.

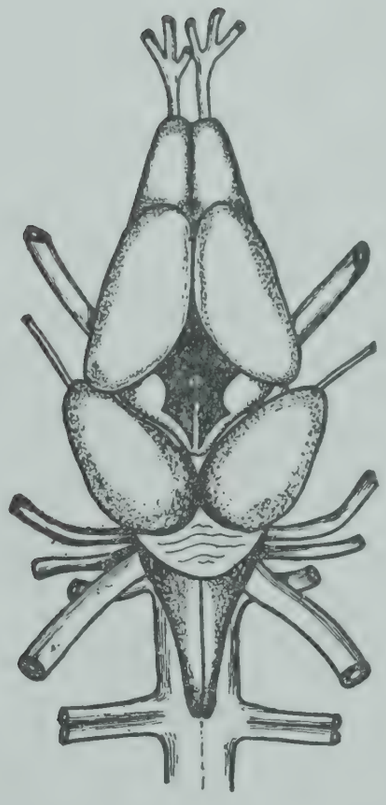


FIG. 57.

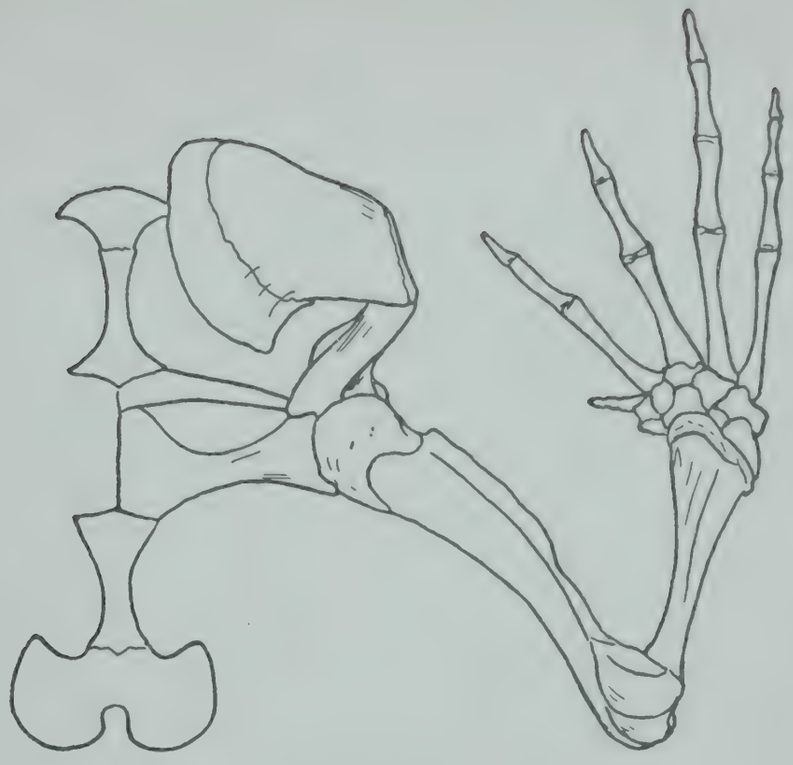


FIG. 58.

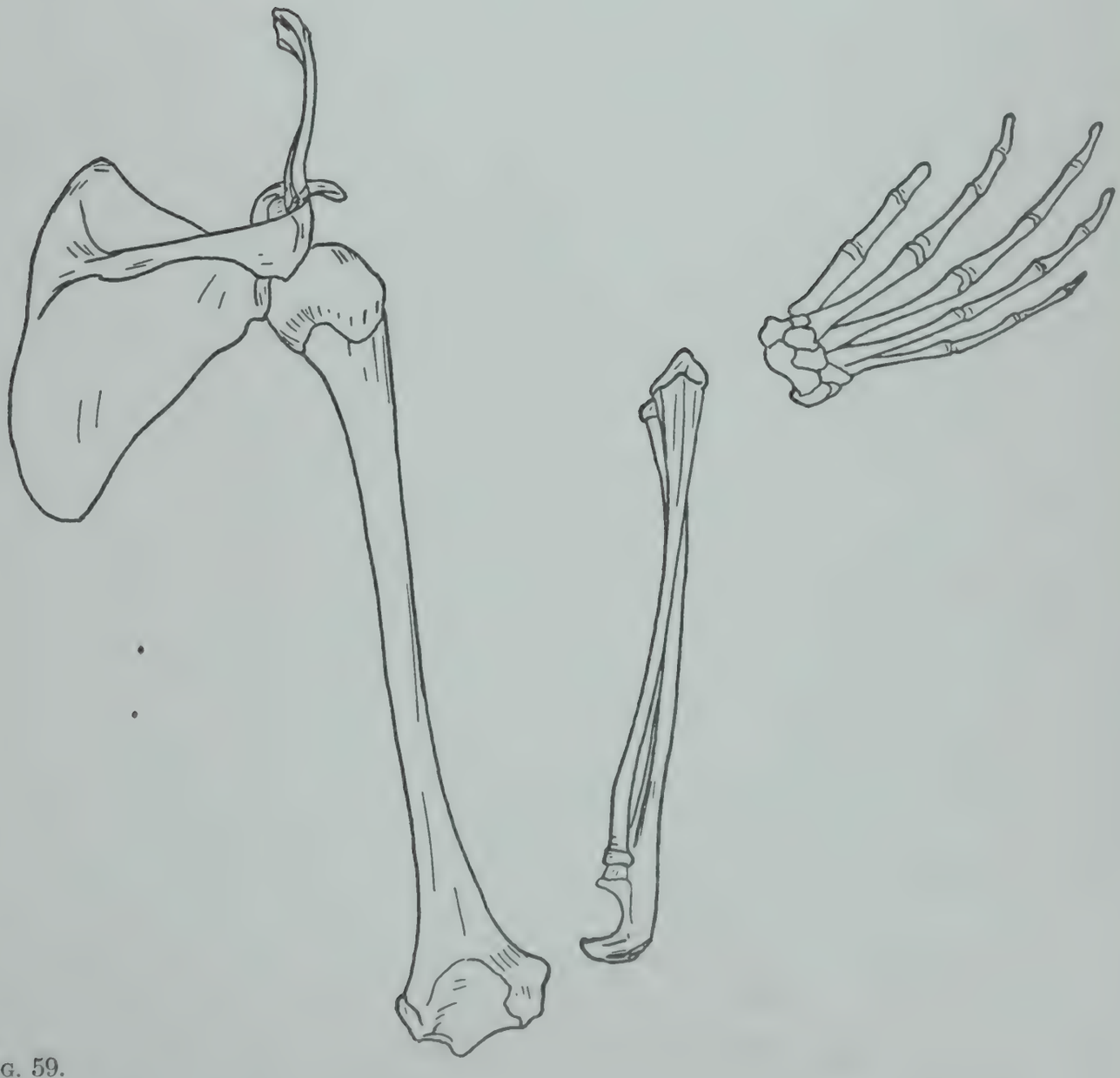


FIG. 59.

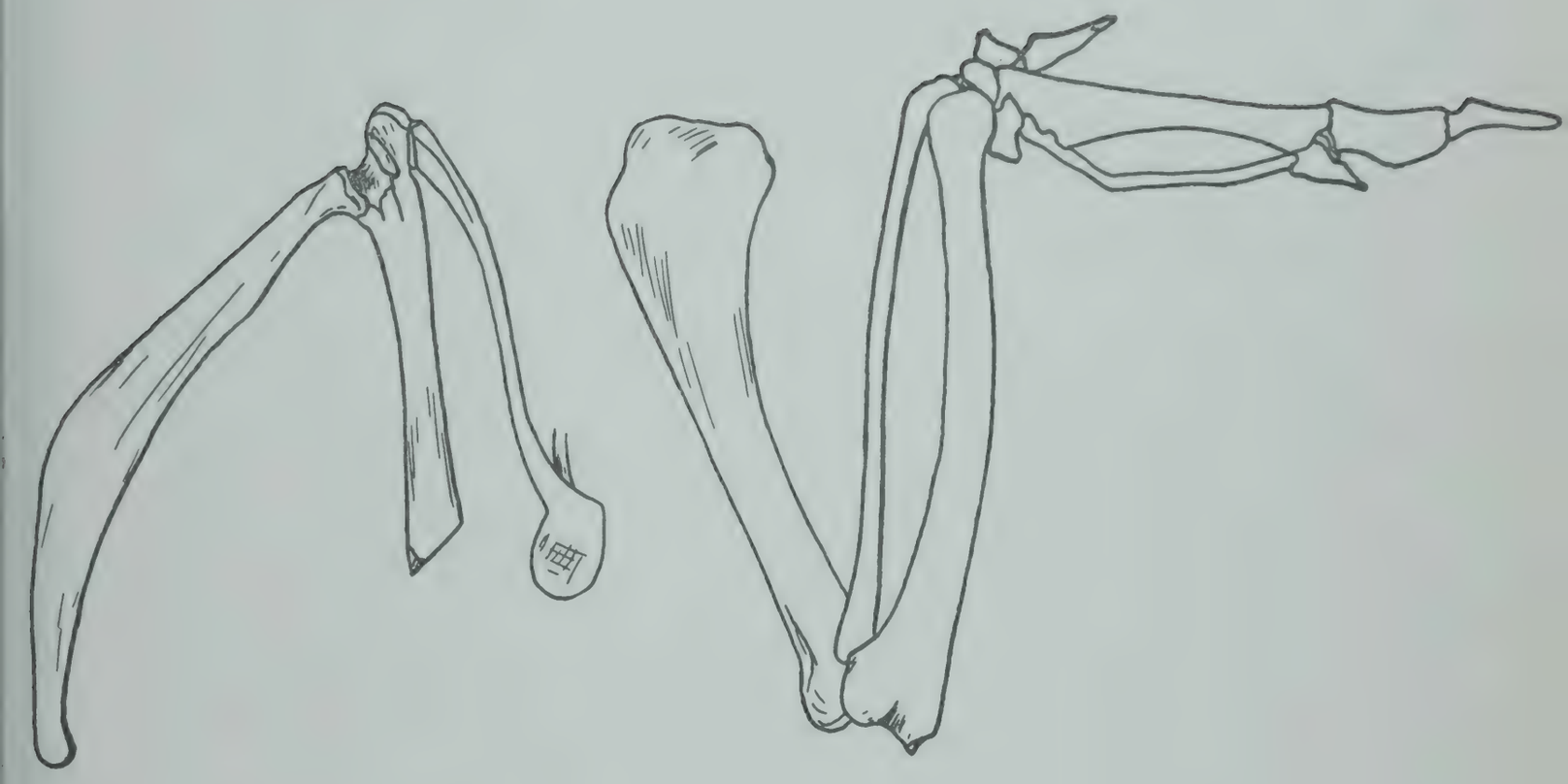


FIG. 60.

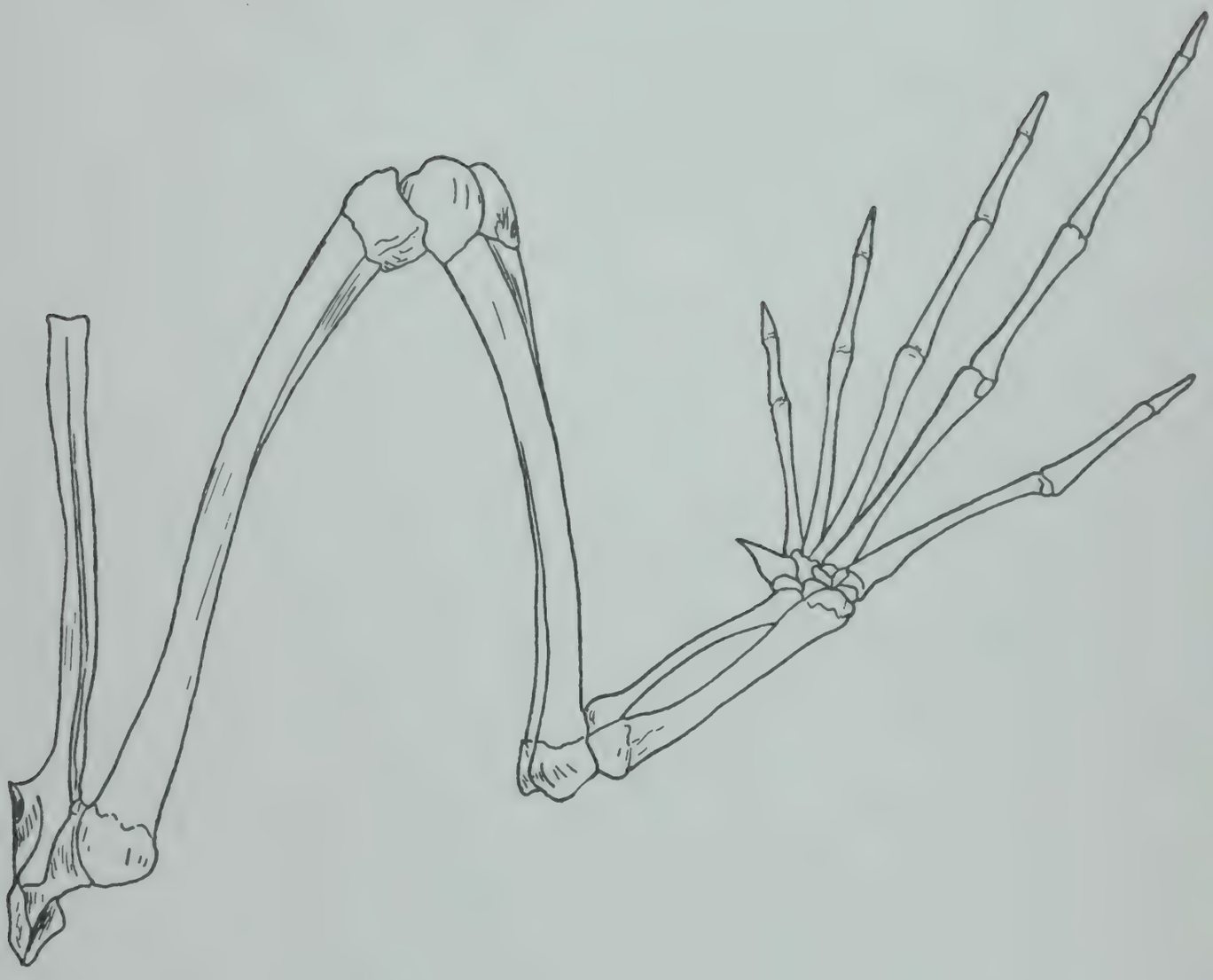


FIG. 61.

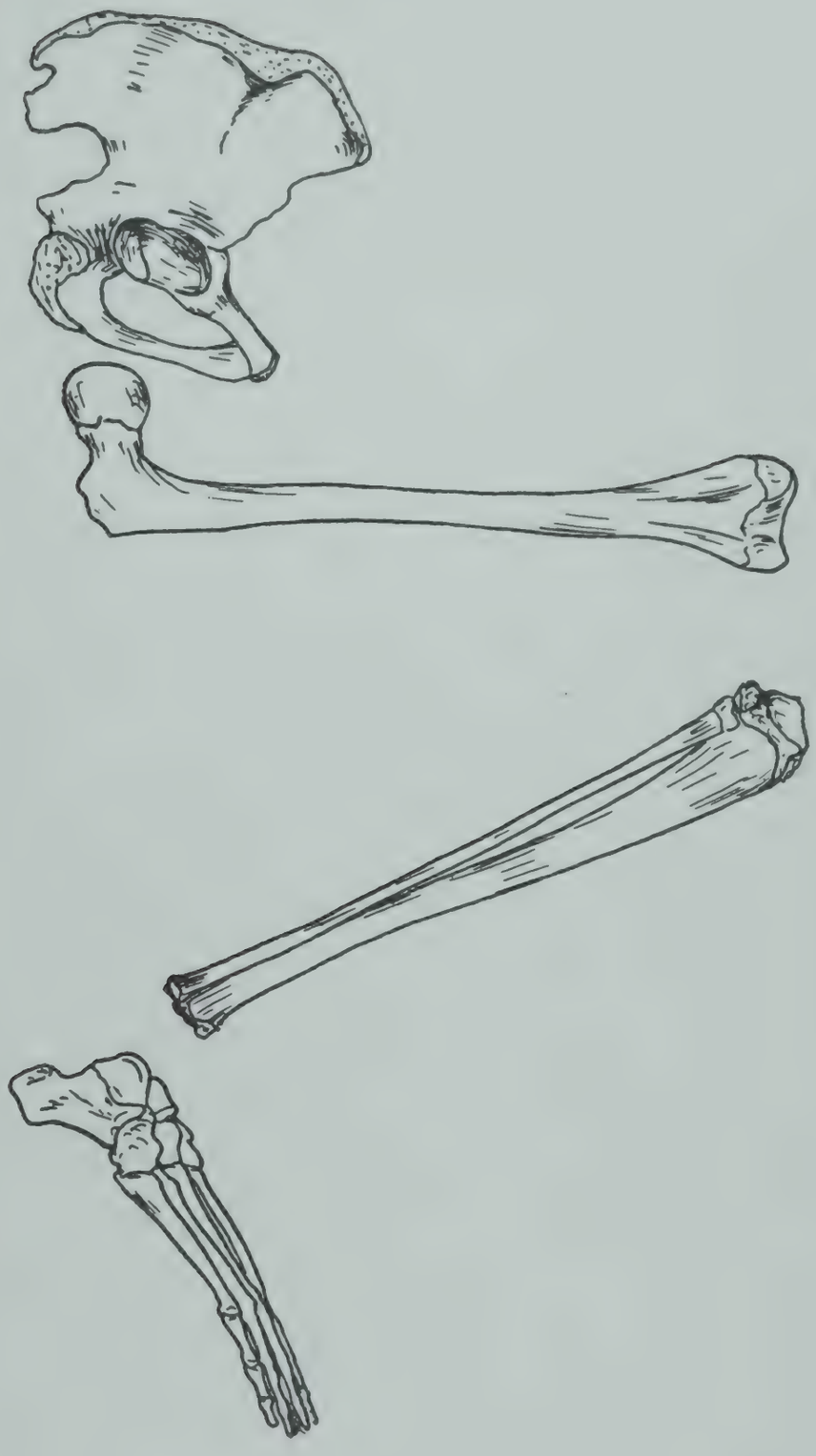


FIG. 62.

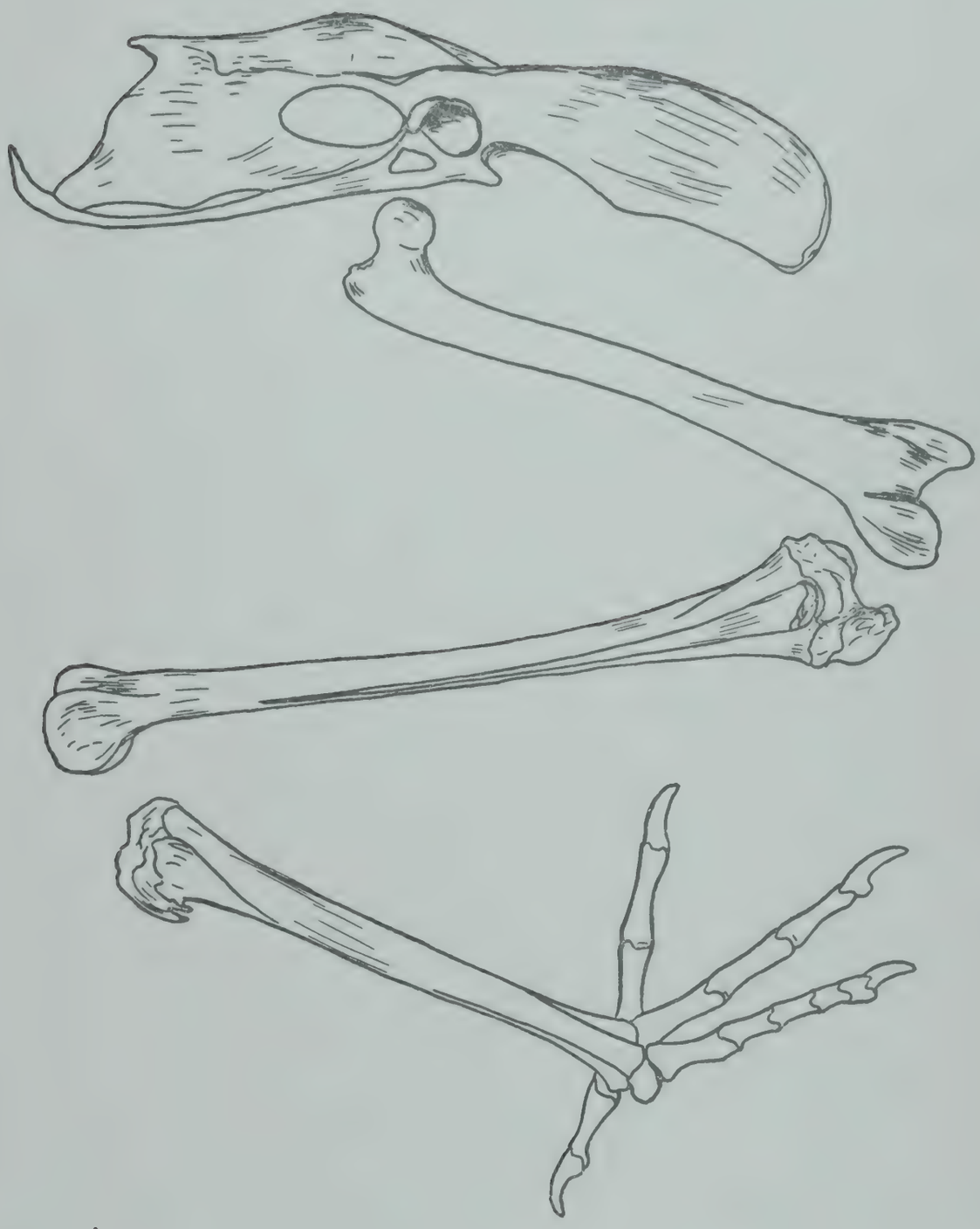


FIG. 63.

FIG. 64. Comparison of the Girdles and Limbs of Frog, Chicken and Man

Name of Bone	Frog	Chicken	Man
Ex: Tibia	Present-fused	Present-fused	Present free

Fig. 65.

Fig. 66.

Fig. 67.

Fig. 68.

Fig. 69.

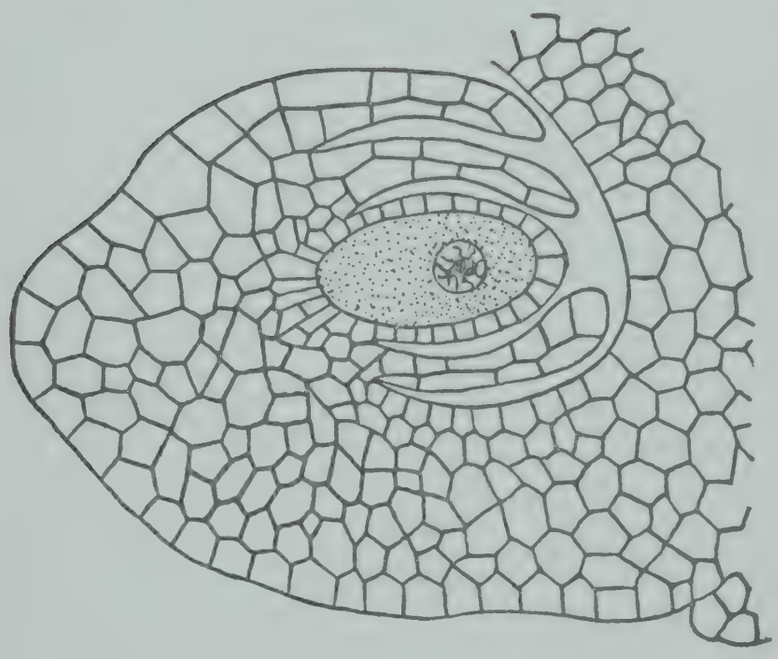


FIG. 70.

Fig. 71.

Fig. 72.

Fig. 73.

Fig. 74.

Fig. 75.

Fig. 76.

Fig. 77.

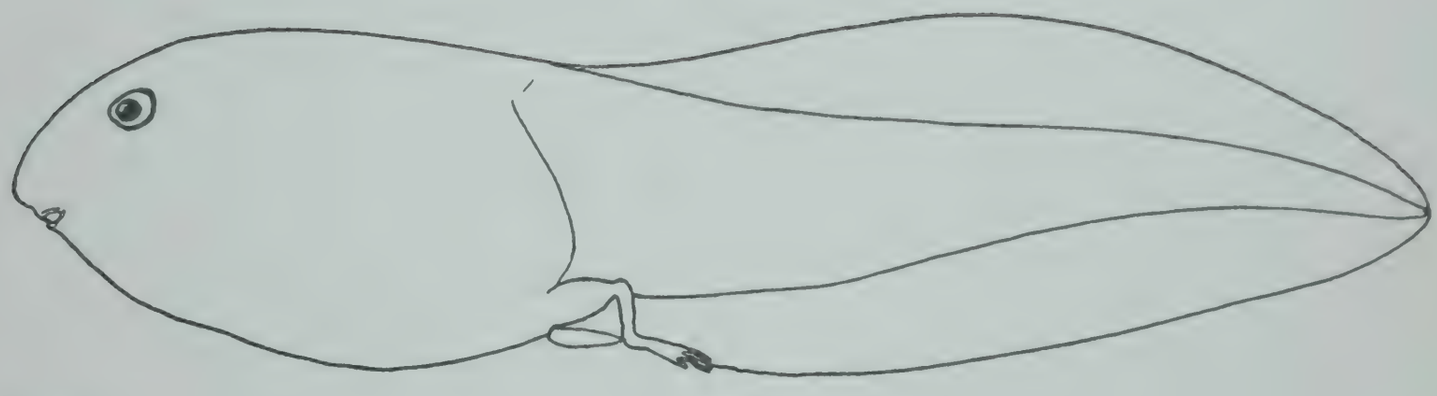


FIG. 78.

Fig. 79.

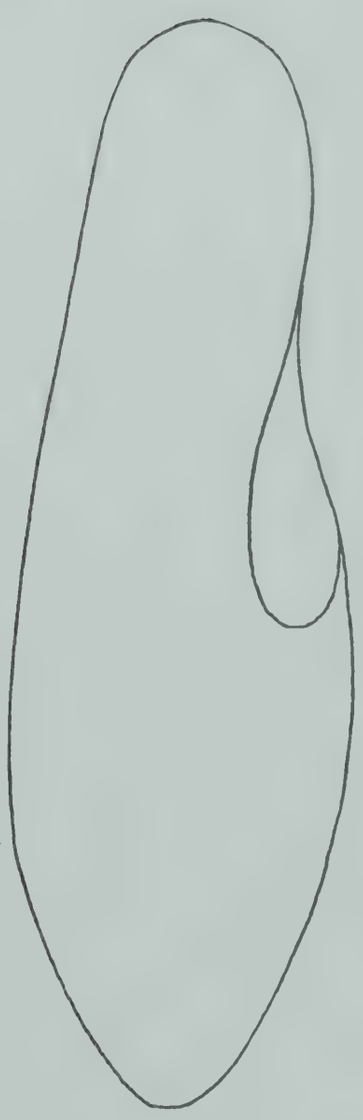


FIG. 80.

Fig. 81.

Fig. 82.

Fig. 83.

Fig. 84.

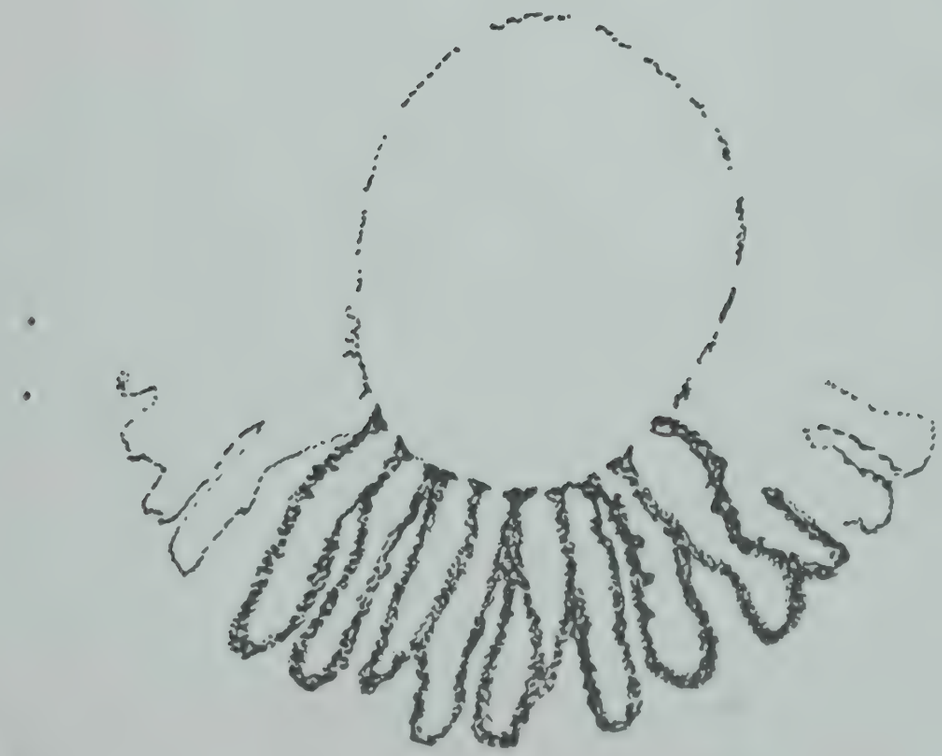


Fig. 85.

Fig. 86.

Fig. 87.

Fig. 88.

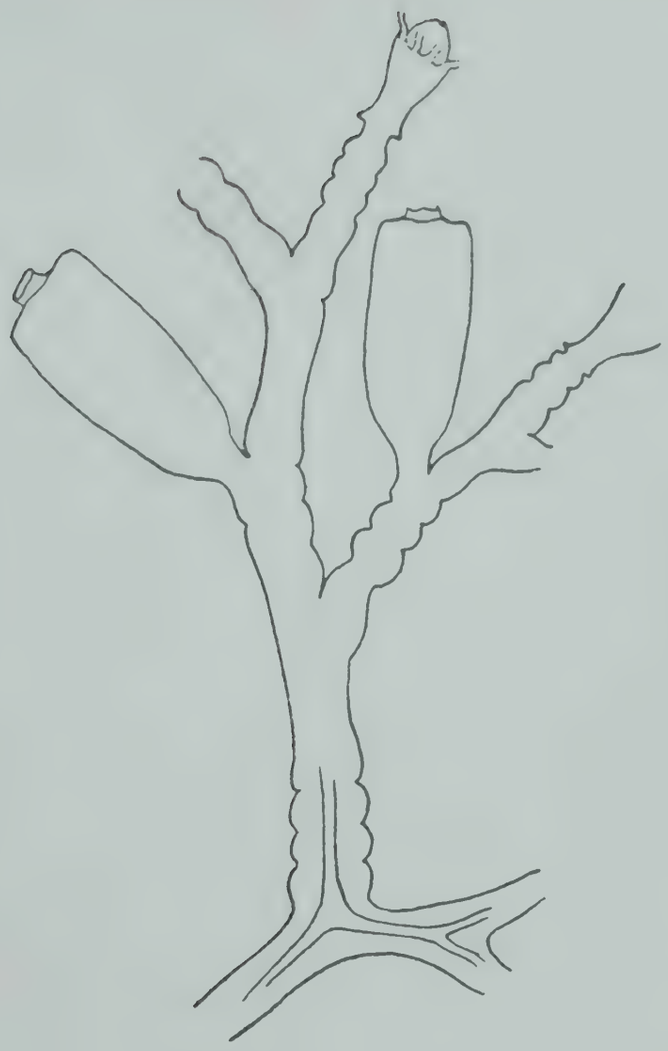


Fig. 89.

Fig. 90.

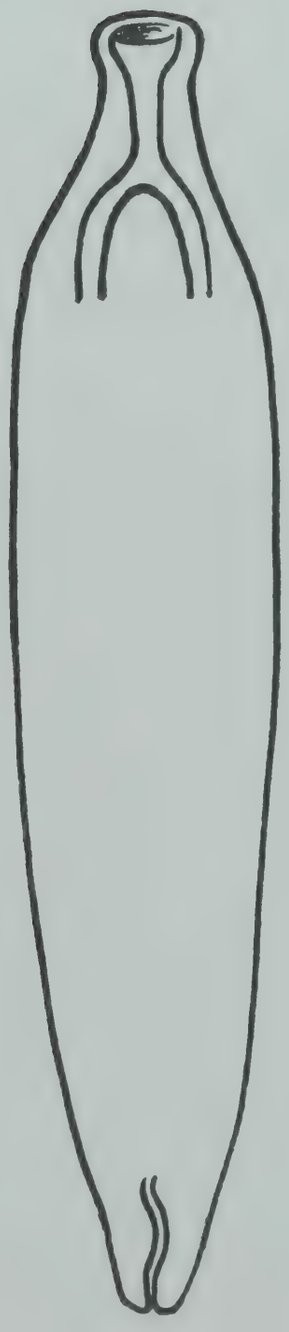


Fig. 91.

Fig. 92.

Fig. 93.

Fig. 94.

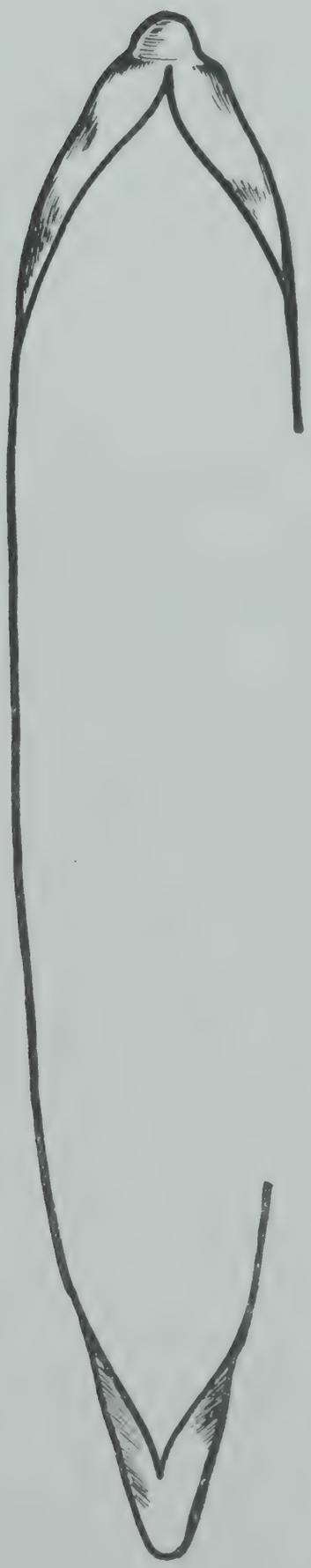


Fig. 95.

FIG. 96.

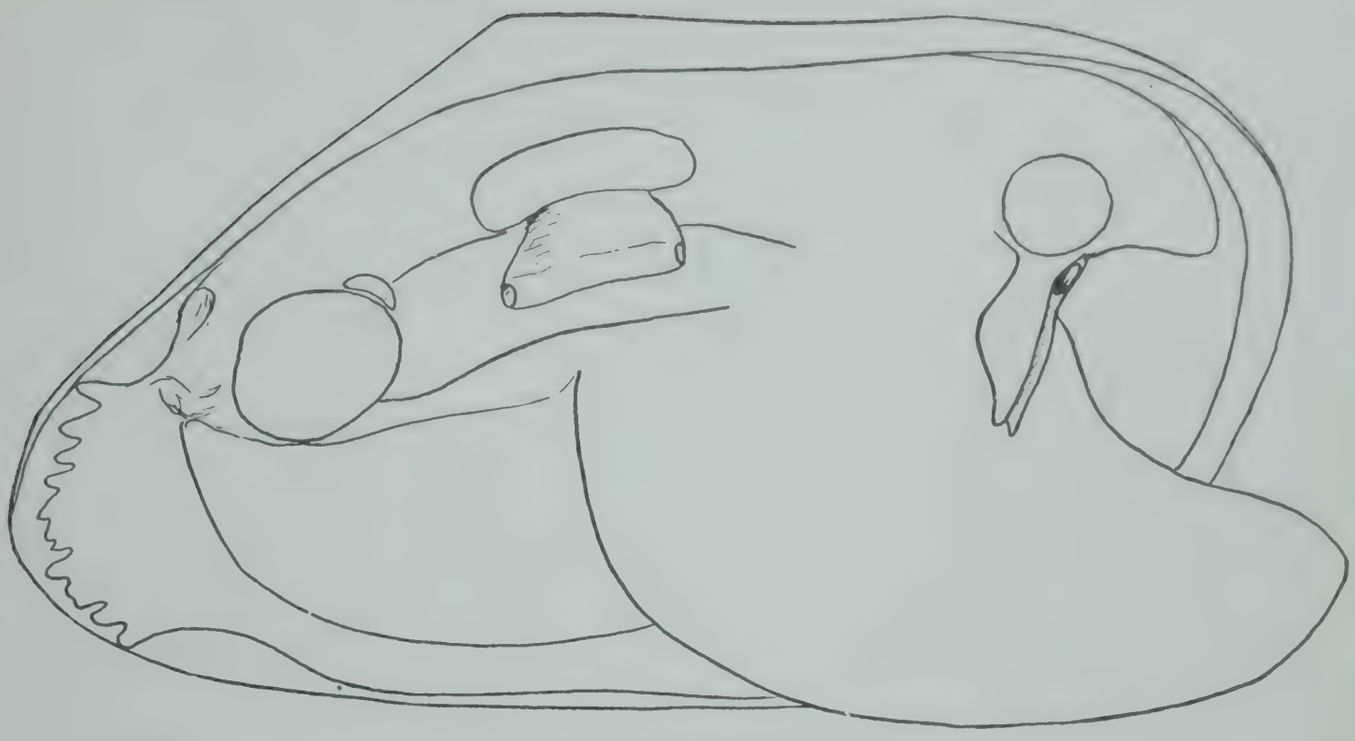


FIG. 97A.

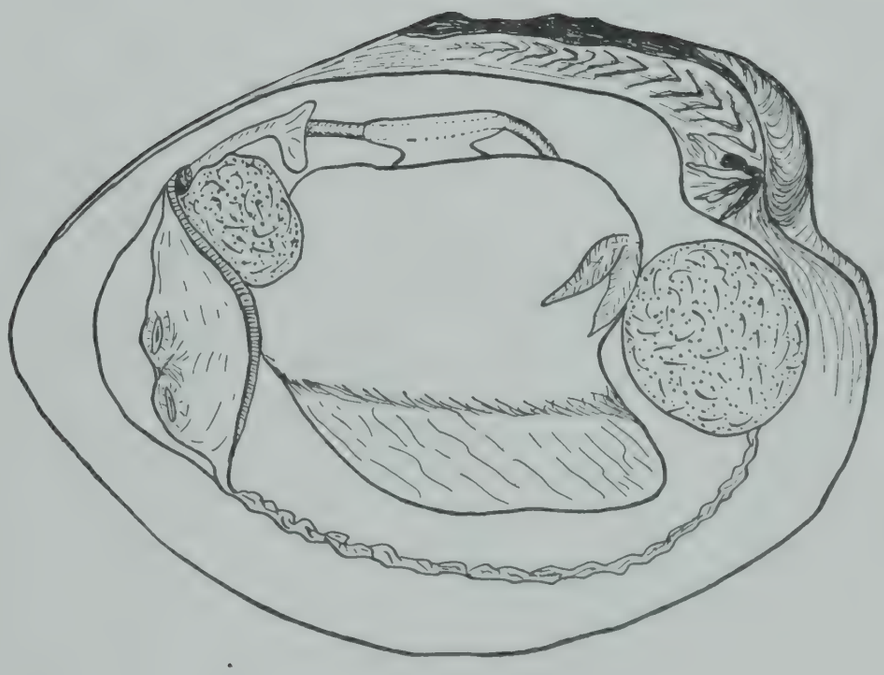


FIG. 97B.

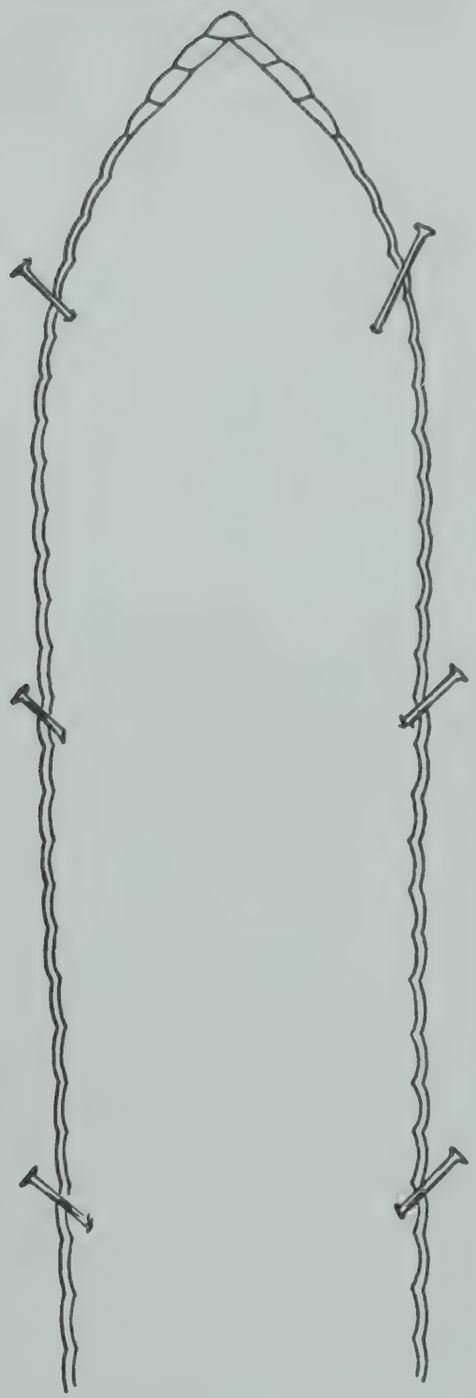


Fig. 98.

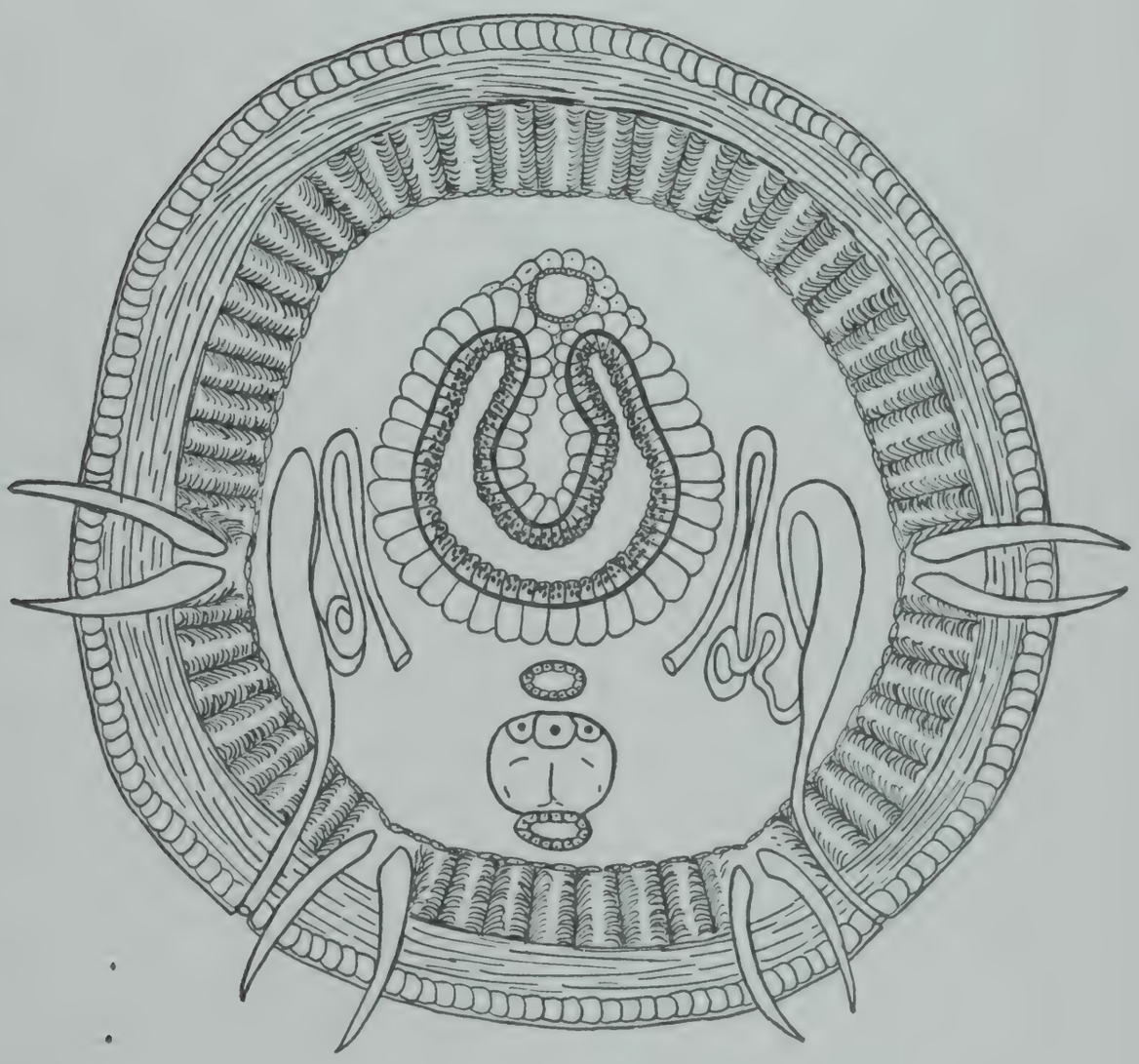
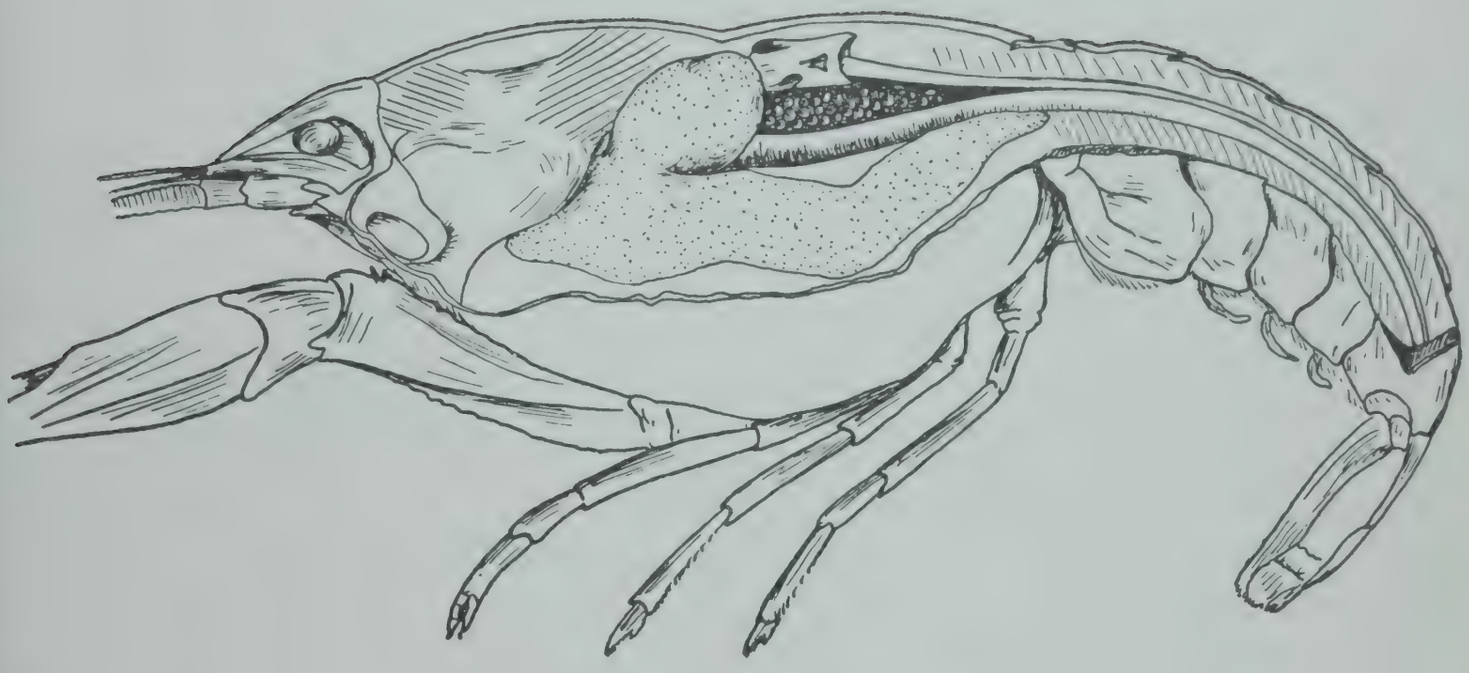


Fig. 99.



IG. 100.

IG. 101.

IG. 102.

Fig. 103.

Fig. 104.

Fig. 105.

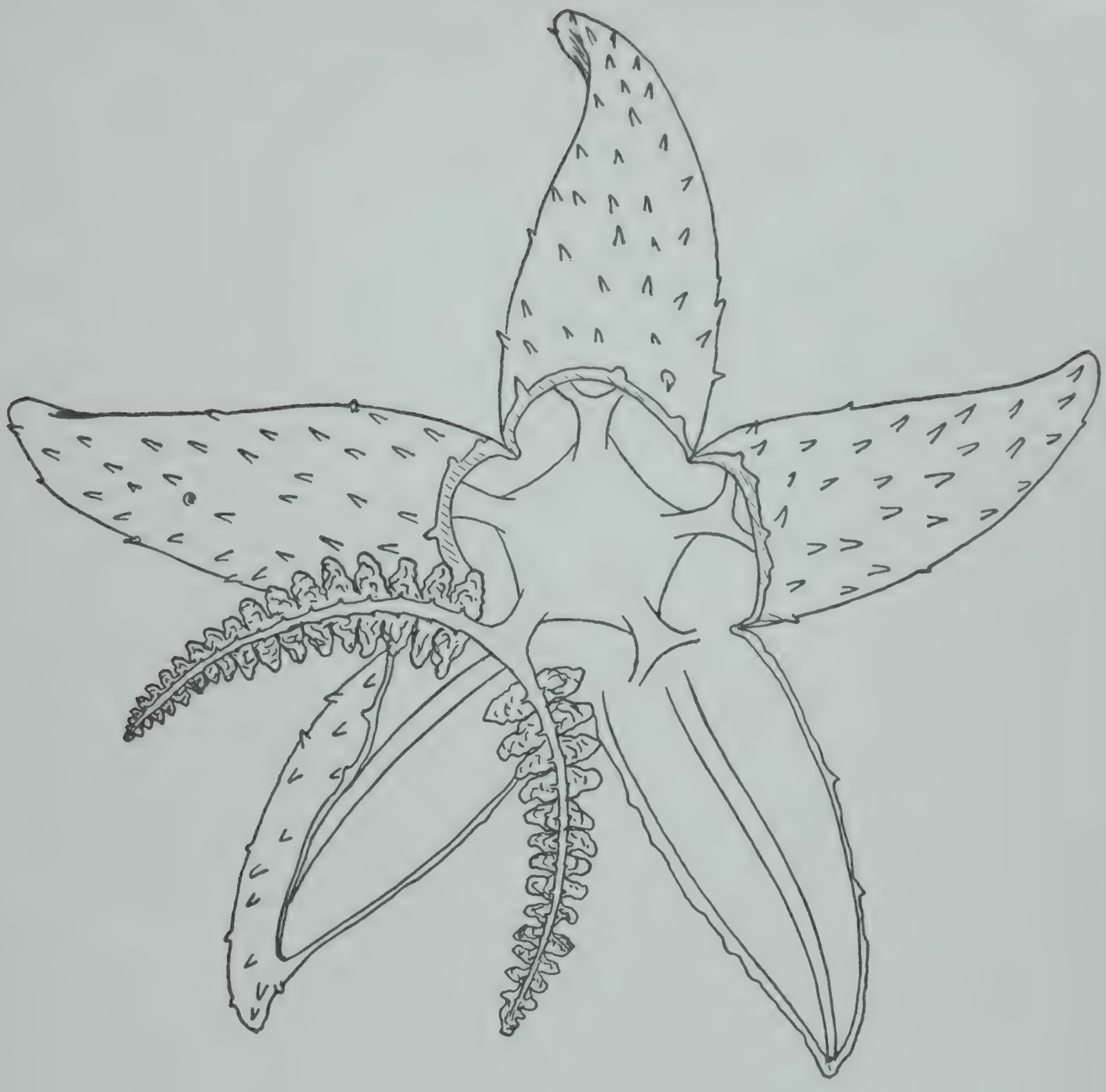


Fig. 106.

FIG. 107.

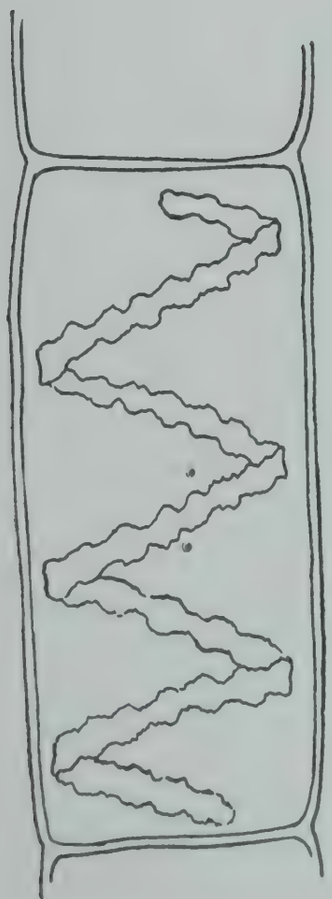
IG. 108.

FIG. 109.

FIG. 110.

FIG. 111.

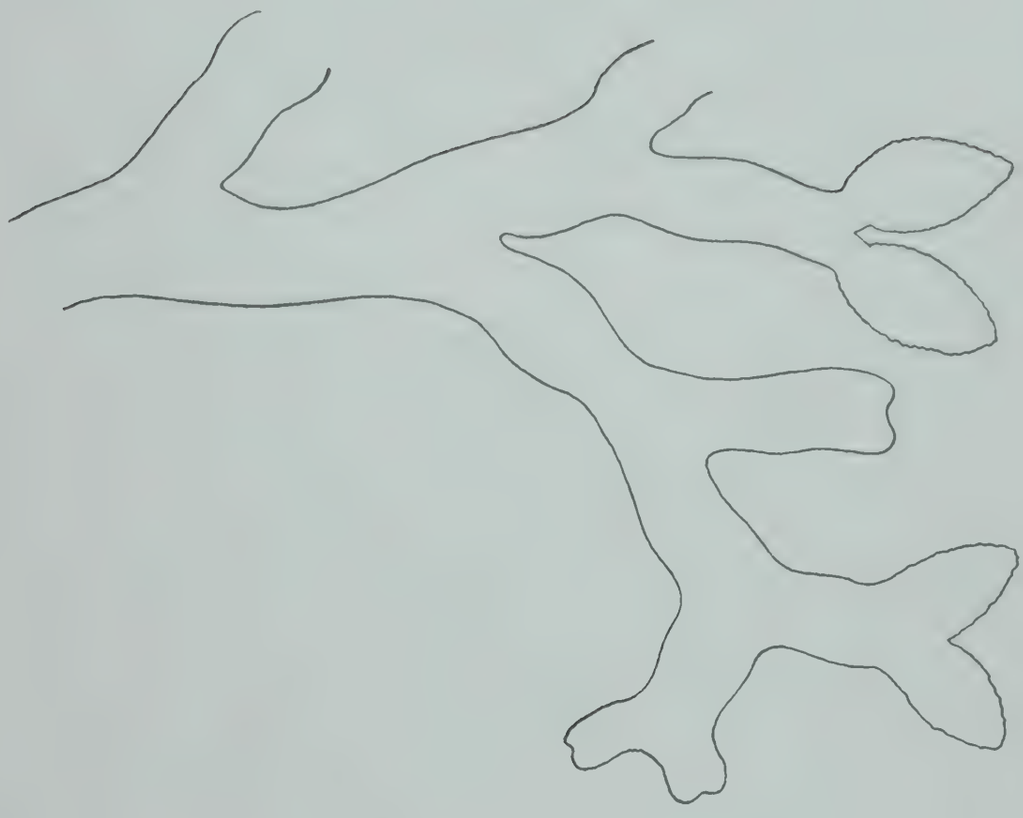
IG. 112.



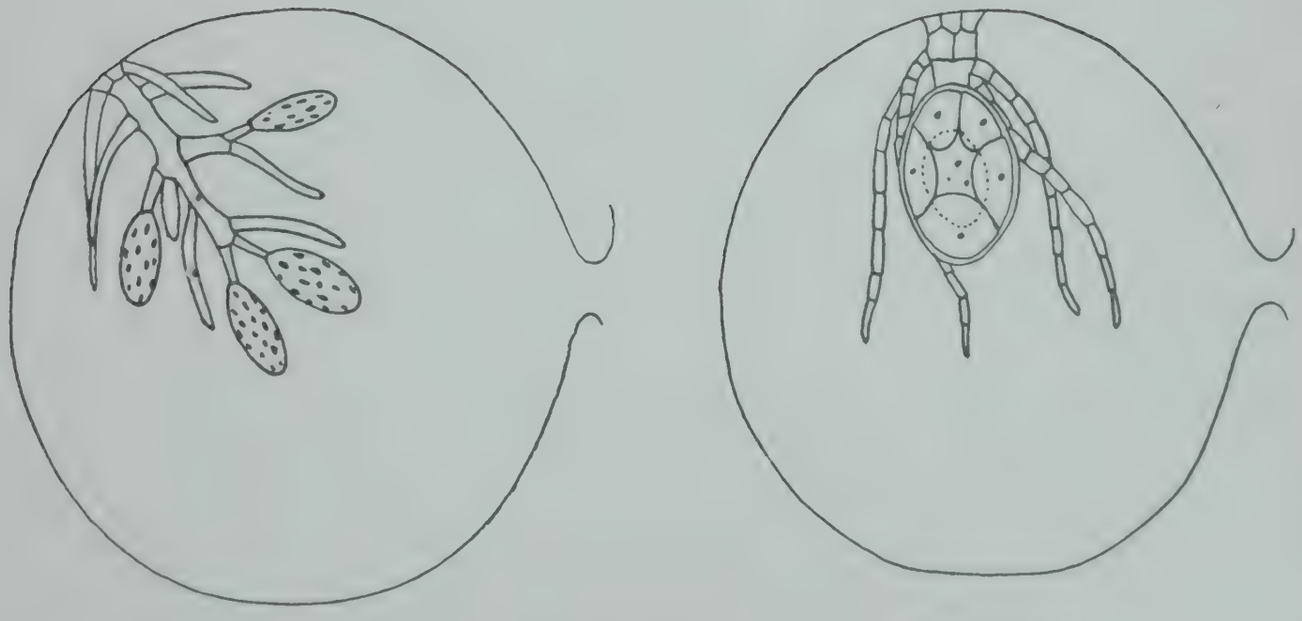
IG. 113.

IG. 114.

FIG. 115.



IG. 116.



IG. 117.

Fig. 118.

Fig. 119.

G. 120.

FIG. 121. Distribution of Bacteria.

Petri Dishes Exposed	Results
To air of laboratory for one-half hour	
To the outside air for one-half hour	
To dirt or scrapings from the hands and covered immediately	
To contact with two or three hairs from the head and covered immediately	

FIG. 123.

3. 122.

FIG. 125.

IG. 124.

IG. 126.

FIG. 127.

FIG. 128.

FIG. 129.

FIG. 130.

FIG. 131.

FIG. 132.

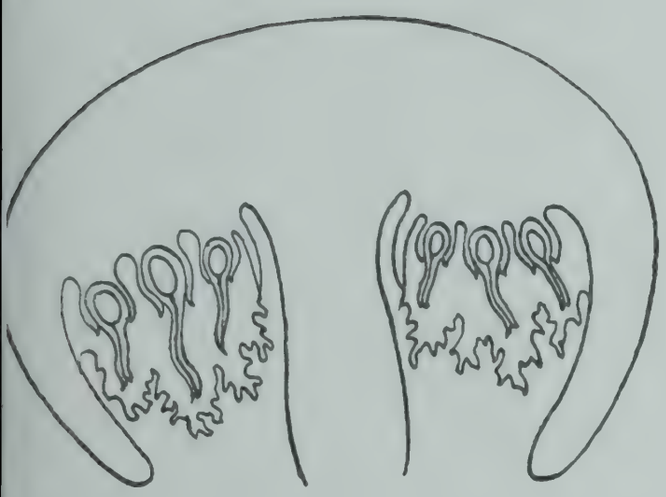


Fig. 133.

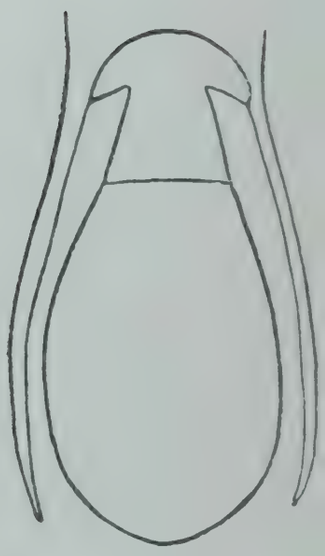
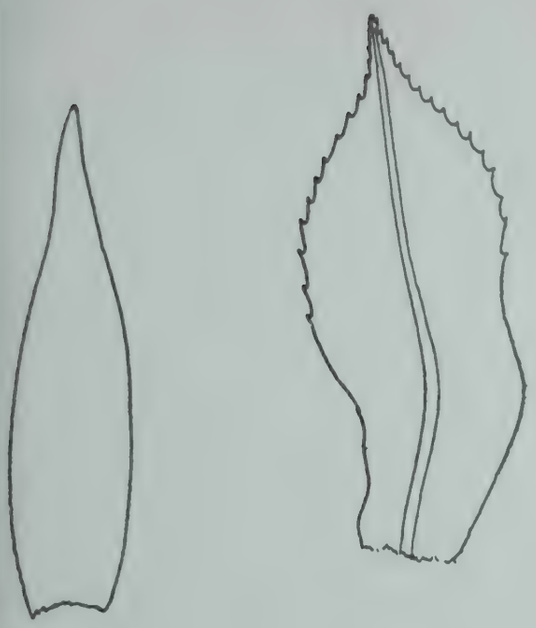


Fig. 134.

Fig. 135.



G. 136.

IG. 137.

FIG. 138.

'IG. 139.

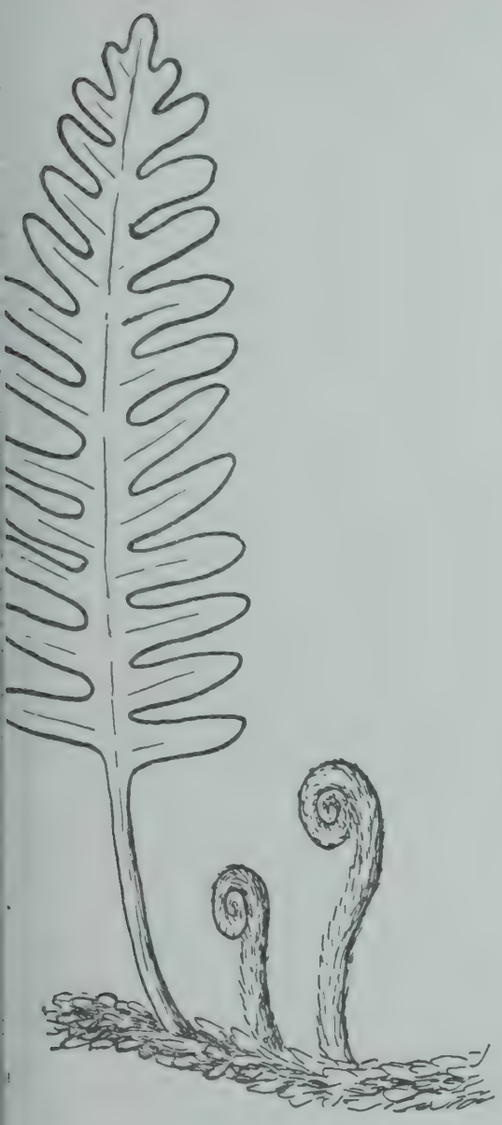


Fig. 140.

Fig. 141.

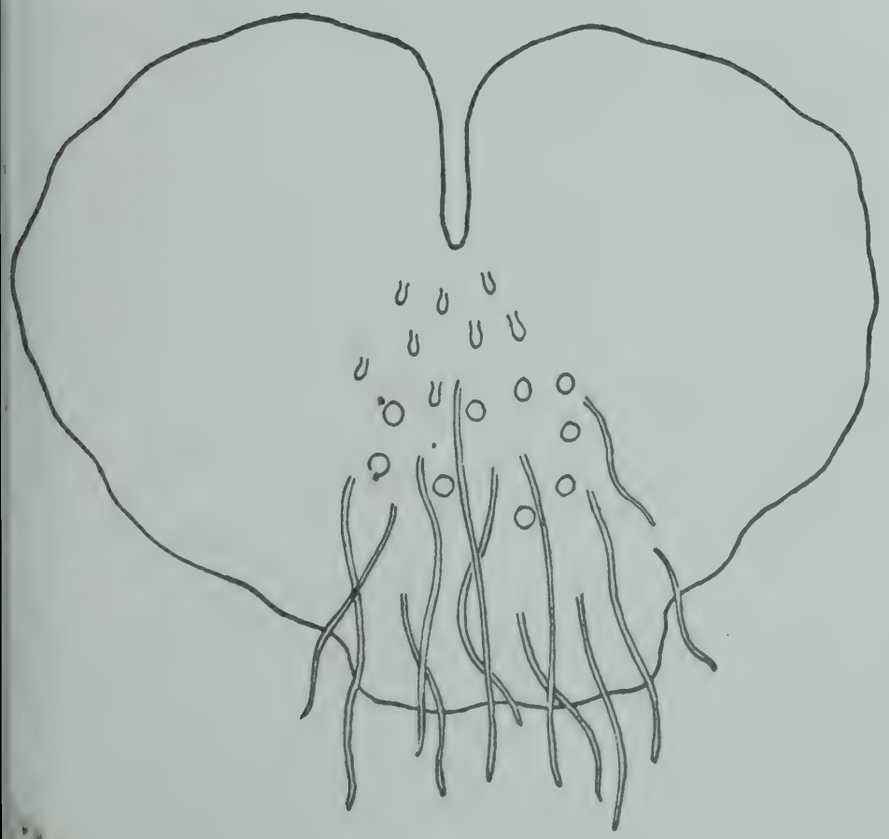


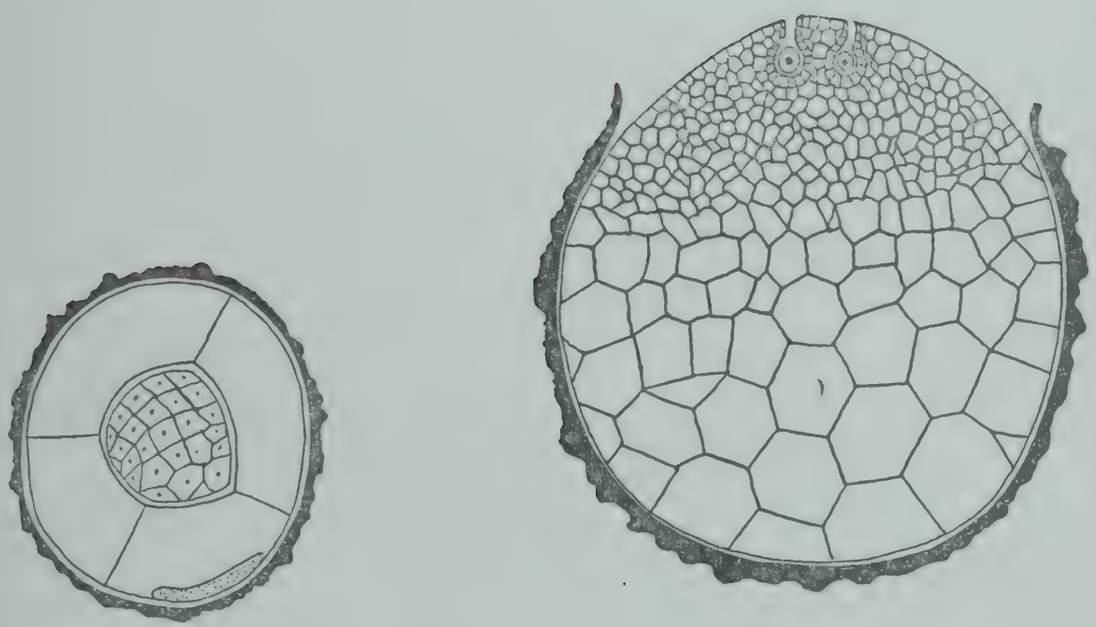
Fig. 142.

Fig. 143.

IG. 144.

FIG. 145.

Fig. 146.



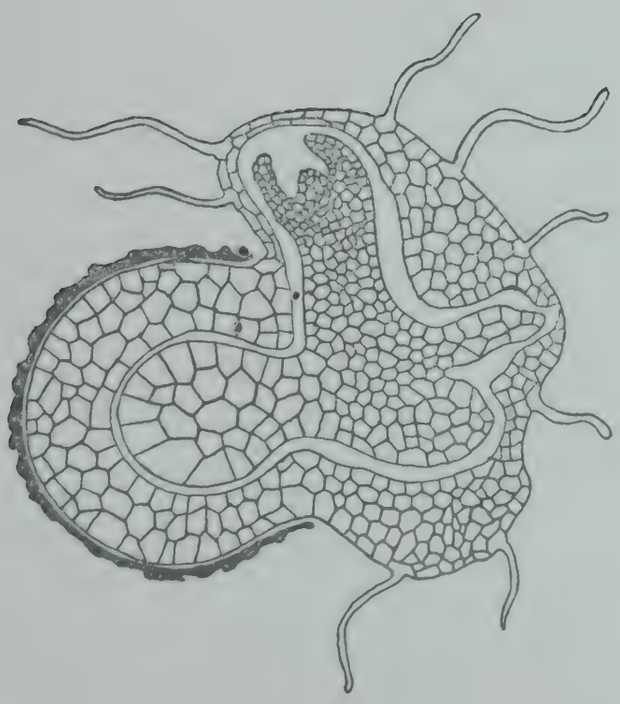


Fig. 147.

Fig. 148.

Fig. 149.

Fig. 150.

Fig. 152.

Fig. 151.

Fig. 153.

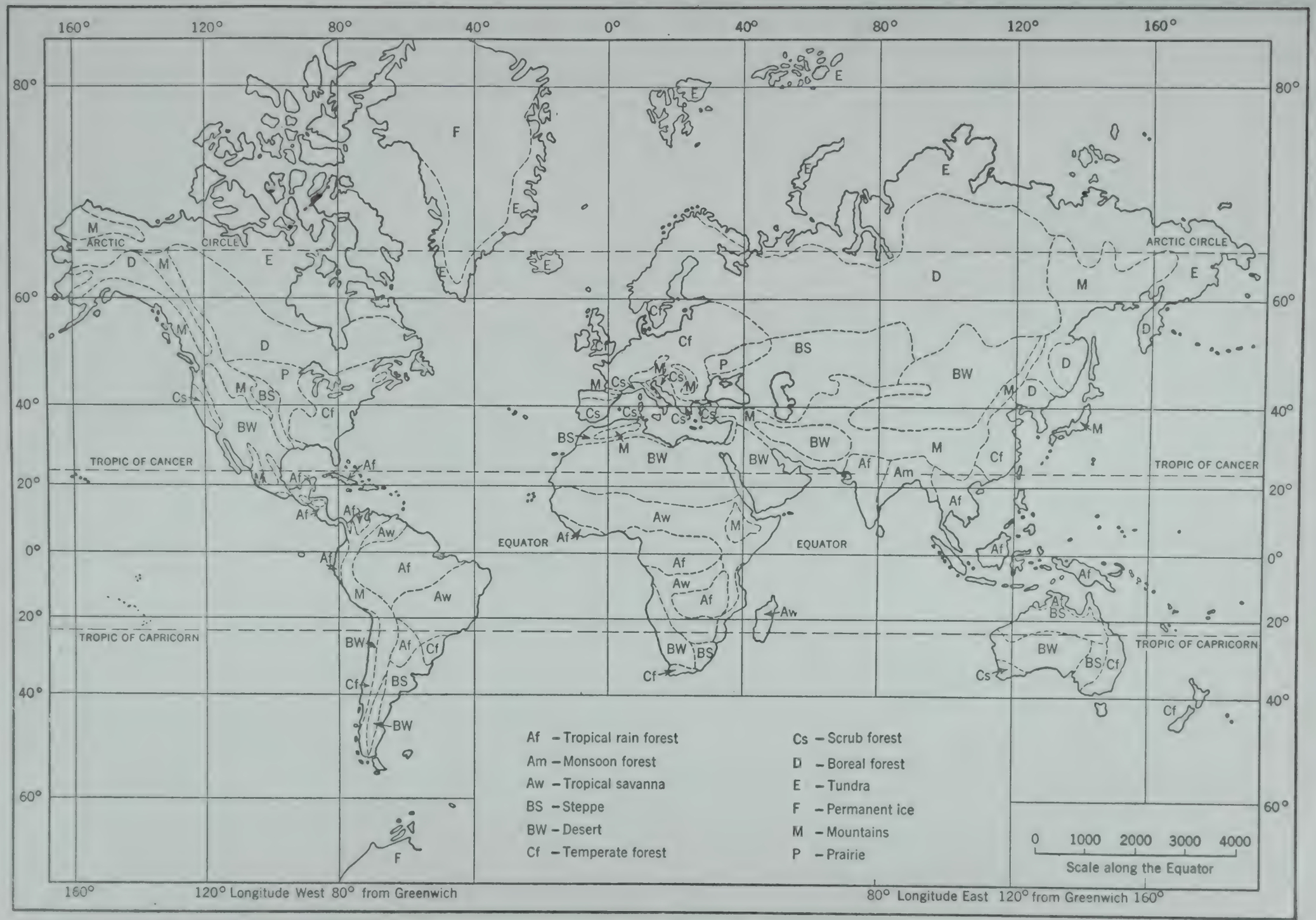
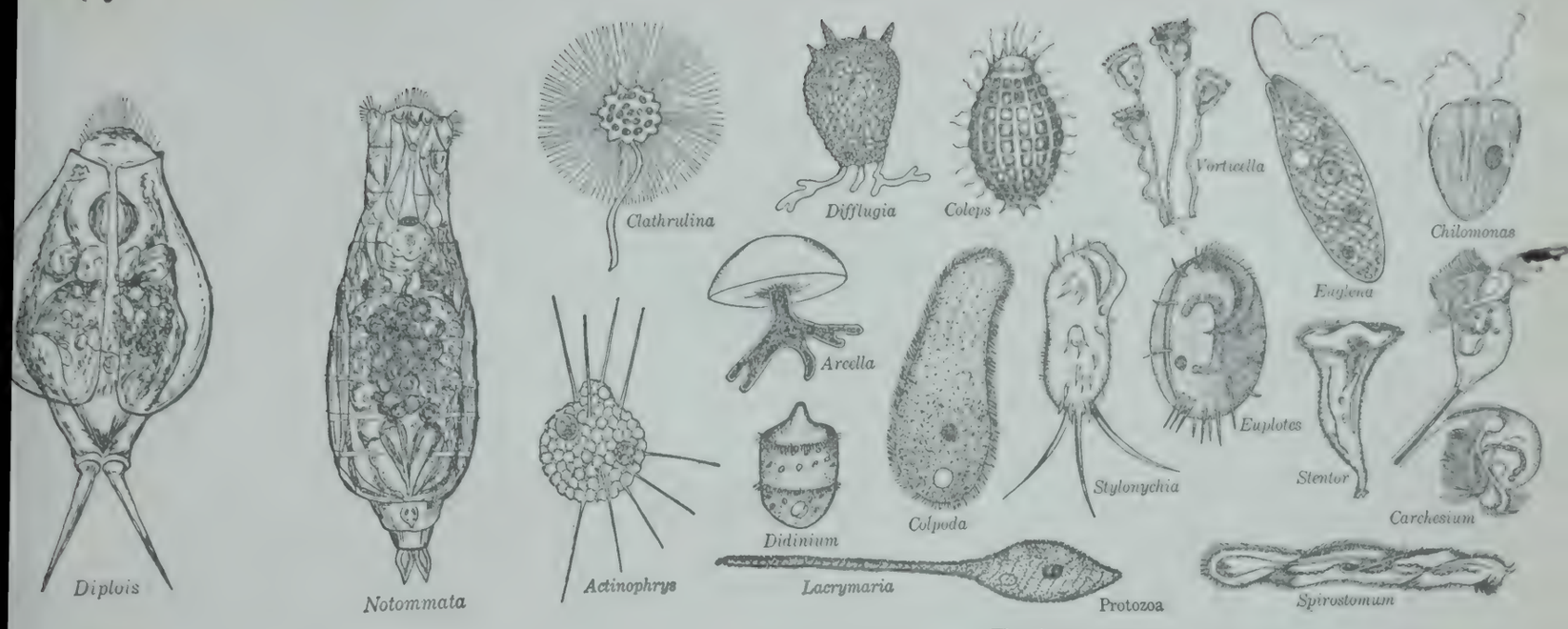

160°
120°
80°
40°
0°
40°
80°
120°
160°
80°
60°
40°
20°
0°
20°
40°
60°
ARCTIC CIRCLE
TROPIC OF CANCER
EQUATOR
TROPIC OF CAPRICORN
120° Longitude West 80° from Greenwich
80° Longitude East 120° from Greenwich 160°
Af – Tropical rain forest
Am – Monsoon forest
Aw – Tropical savanna
BS – Steppe
BW – Desert
Cf – Temperate forest
Cs – Scrub forest
D – Boreal forest
E – Tundra
F – Permanent ice
M – Mountains
P – Prairie
0 1000 2000 3000 4000
Scale along the Equator

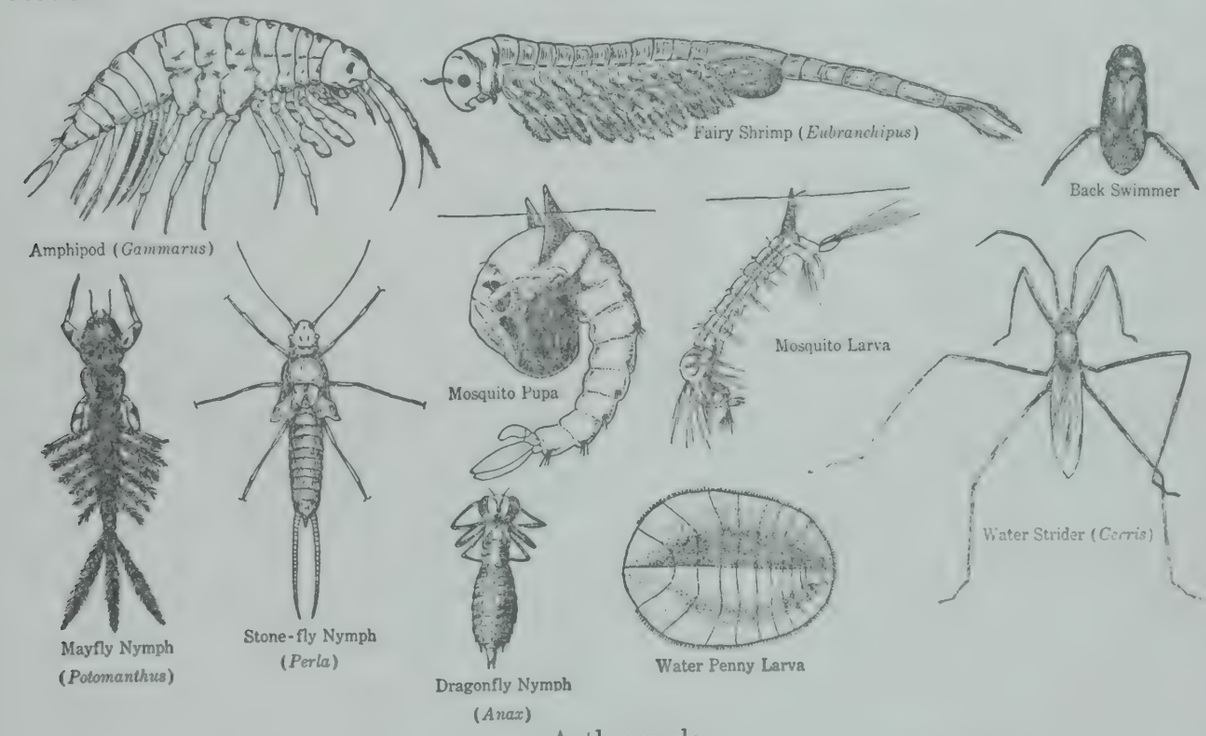
FIG. 154.

Fig. 155.

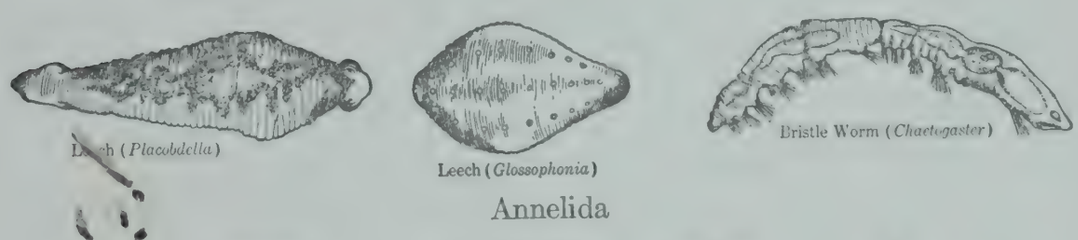


Rotifera

Protozoa



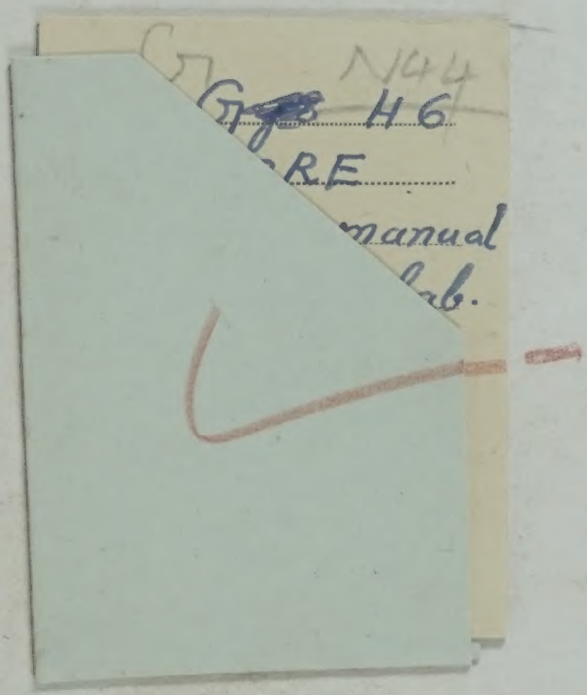
Arthropoda



Annelida

Microscopic Plants

FIG. 156. Some Aquatic Animals and Plants.


N44
46
manual